Università di Trieste: FISICA SPAZIALE

"Laboratorio di Astrofisica Spaziale"

Analisi dell'ambiente spaziale: studio del Sole, dell'atmosfera terrestre e della loro interazione; astrodinamica con studio particolareggiato delle orbite e delle caratteristiche di una missione spaziale (propulsione, trasmissione dati, …)

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Sommario

- Corso:
  - Programma, orario, materiale, esami, disponibilita'
- Motivazioni & Storia
- Astrofisica
- Astronomia
- Fisica della Terra
- Programmi Commerciali
- Programmi Educativi: AtmoCube
- Conclusioni

Programma del Corso 1/2

1. INTRODUZIONE ALLA FISICA SPAZIALE
   - Scopi dell'esplorazione spaziale
   - Storia dell'esplorazione dello spazio
2. IL SOLE E L'AMBIENTE CIRCOSTANTE LA TERRA
   - Il Sole
   - L'atmosfera
   - La ionosfera
   - La magnetosfera
   - Le fasce di radiazione di Van Allen
3. INTRODUZIONE ALL'ASTRODINAMICA
   - Orbite kepleriane
   - Generalità sulle orbite
   - Cambiamenti d'orbita
   - Scelta dell'orbita per un satellite astronomico

Programma del Corso 2/2

4. GEOMETRIA DI UNA MISSIONE SPAZIALE
   - Geometria sulla sfera celeste
5. PROPULSIONE E POTENZA NELLO SPAZIO
   - Caratteristiche dei motori per razzi
   - Sistemi di propulsione
   - Sistemi di potenza
6. SISTEMI D'ASSETTO
   - Guida e controllo d'assetto
   - Sensori d'assetto
7. ULTERIORI SISTEMI DI UN SATELLITE
   - Sistema termico di un satellite
   - Struttura di un satellite
   - Telecomunicazioni di un satellite

Orario & materiale

- Mattino:
  - Lunedì 9-11 e Mercoledì 11-13 Aula E
- Pomeriggio:
  - Lunedì 14-18, Mercoledì 14-18 Aula E

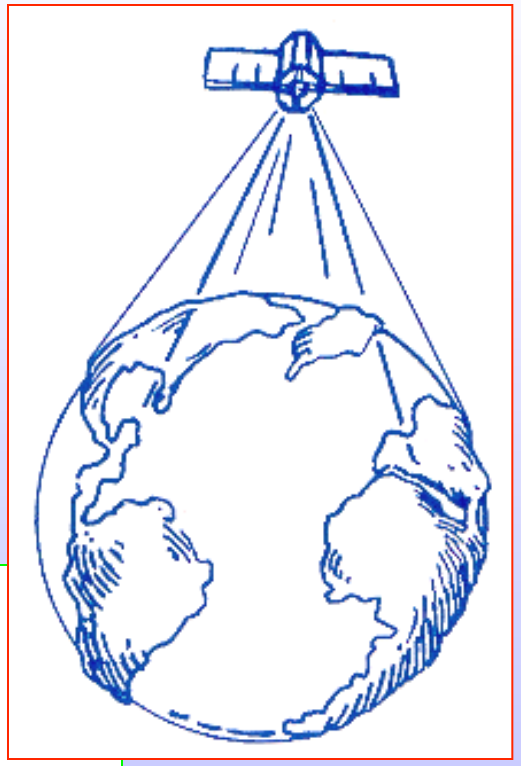
- Materiale
  - Dispense (Italiano)
  - Fotocopie e file trasparenze (Italiano)
  - Tutto su “Moodle” http://moodle.units.it/moodle/
  - Libro di riferimento: “Space Mission Analysis and Design” (SMAD), J.R. Wertz and W.J. Larson, 3rd edition, Space Technology Library (in biblioteca)

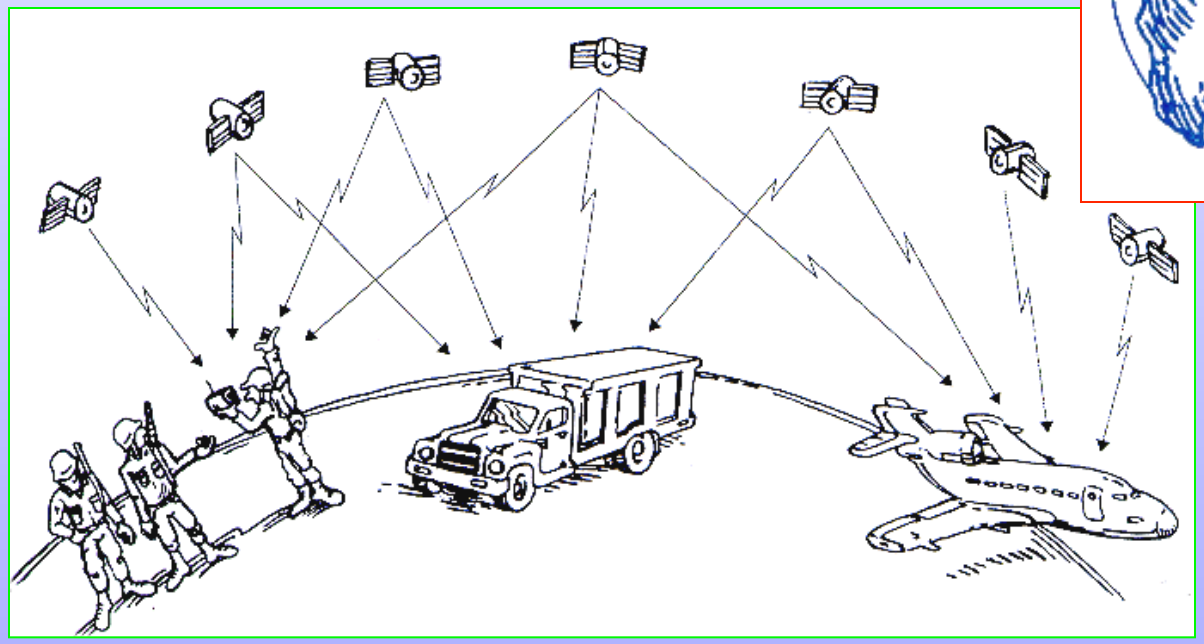
Esame & disponibilità

- Esame:
  - Seminario di 20 minuti con un approfondimento di un argomento a piacere (consiglio: venite a parlarne prima)
  - Due o tre domande sul programma
  - Avvisare almeno una settimana prima
- Disponibilità:
  - E.mail o telefono, ricevimento all'Università (mer. 9-10)
  - Richiesta: lista e-mail e un cellulare di (almeno) una persona di riferimento
- Altro:
  - PC a disposizione?

Motivazioni 1/2

- Osservazioni della Terra
- Comunicazioni
- Navigazione





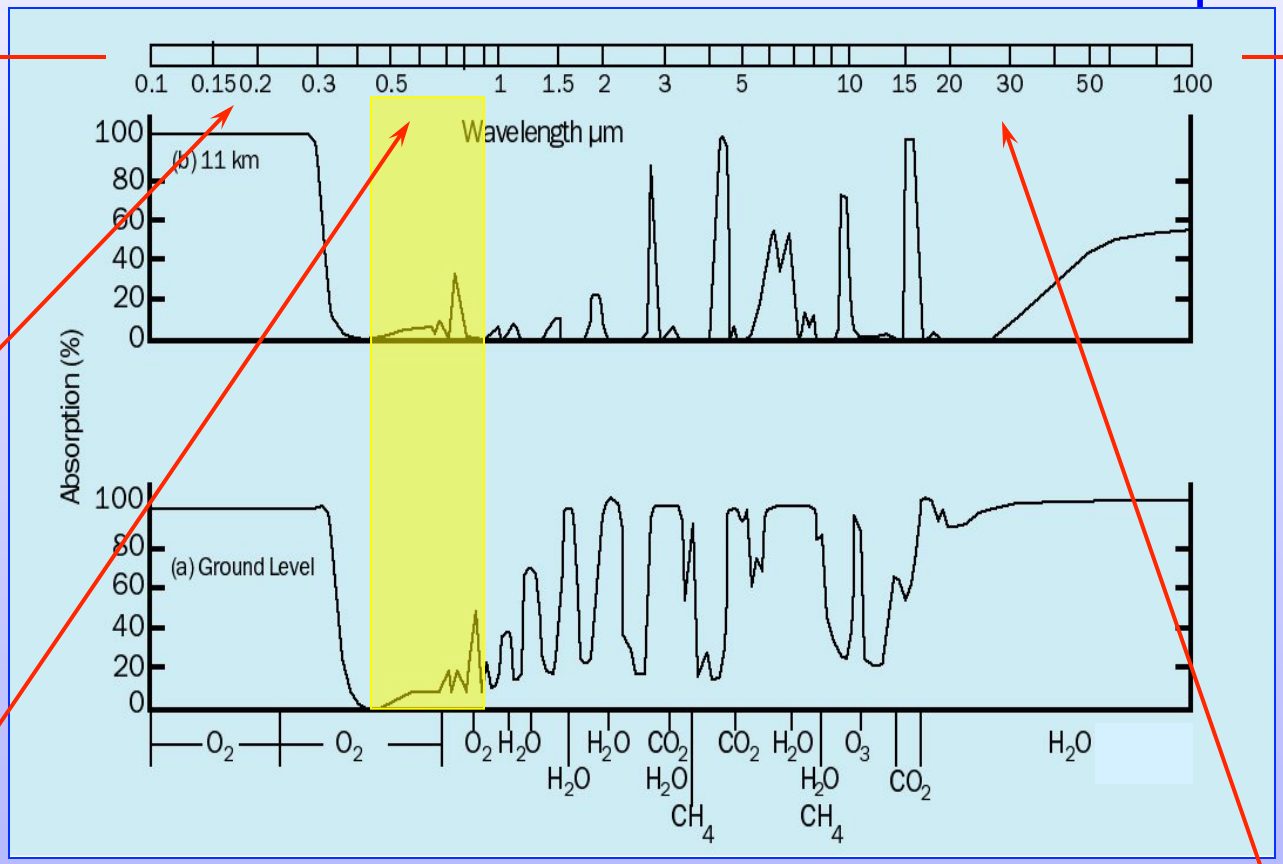
Motivazioni 2/2

- Scienza
- Esplorazione

Atmosfera

Raggi X / γ: gas intergalattico, dischi accrescimento

Microonde / Onde Corte: fondo radiazione cosmica, elettroni in campi magnetici

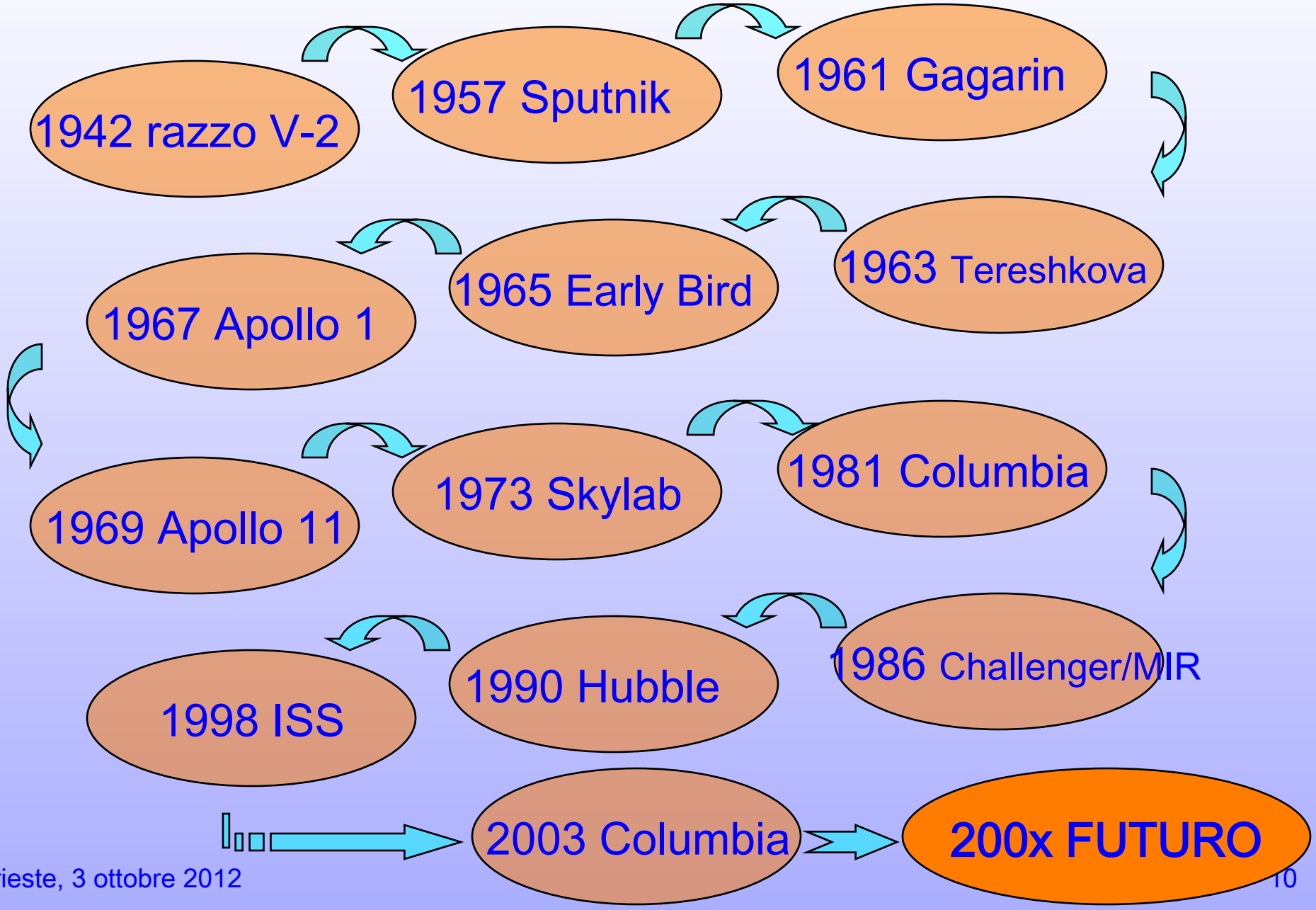


UV: stelle calde

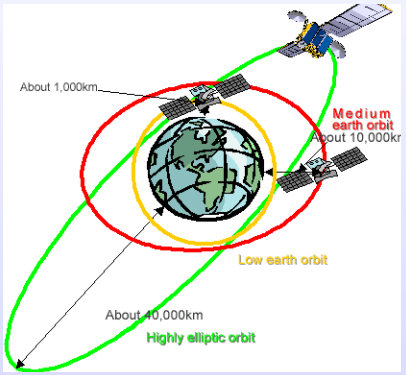
Visibile: stelle fredde

IR: polveri cosmiche, comete

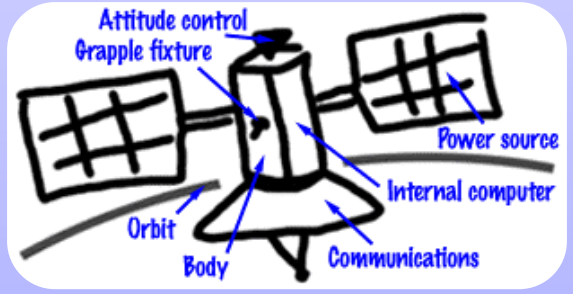
Storia


1942 razzo V-2
1957 Sputnik
1961 Gagarin
1963 Tereshkova
1965 Early Bird
1967 Apollo 1
1969 Apollo 11
1973 Skylab
1981 Columbia
1986 Challenger/MIR
1990 Hubble
1998 ISS
2003 Columbia
200x FUTURO

Una Missione Satellitare



Missione Satellitare



Difficoltà Tecniche 1/2

- Condizioni ostili ambiente spaziale:
  - escursioni termiche
  - vuoto
  - dosi di radiazione cosmica
  - particelle e frammenti
- Problematiche al lancio (vibrazioni)
- Strumentazione di dimensioni, peso e consumi ridotti

Difficoltà Tecniche 2/2

Radiazione nello Spazio (esempio)

Componenti Primarie

- Raggi Cosmici – particelle provenienti dallo spazio profondo
- Particelle Solari – particelle provenienti dal Sole
- Cinture di Radiazione – cinture di particelle energetiche che circondano la Terra

Componenti Secondarie

- Sciami Elettromagnetici – raggi cosmici nell'atmosfera
- Bremsstrahlung – elettroni attraverso un materiale/atmosfera
- Scintillazione (fluorescenza) particelle attraverso l'azoto atmosferico o componenti ottiche
- Radiazione Cherenkov – flash prodotti da particelle ad alta velocità attraverso materiali

Strategia

Navette Spaziali (Shuttle)

- tempo in orbita breve
- recupero della strumentazione

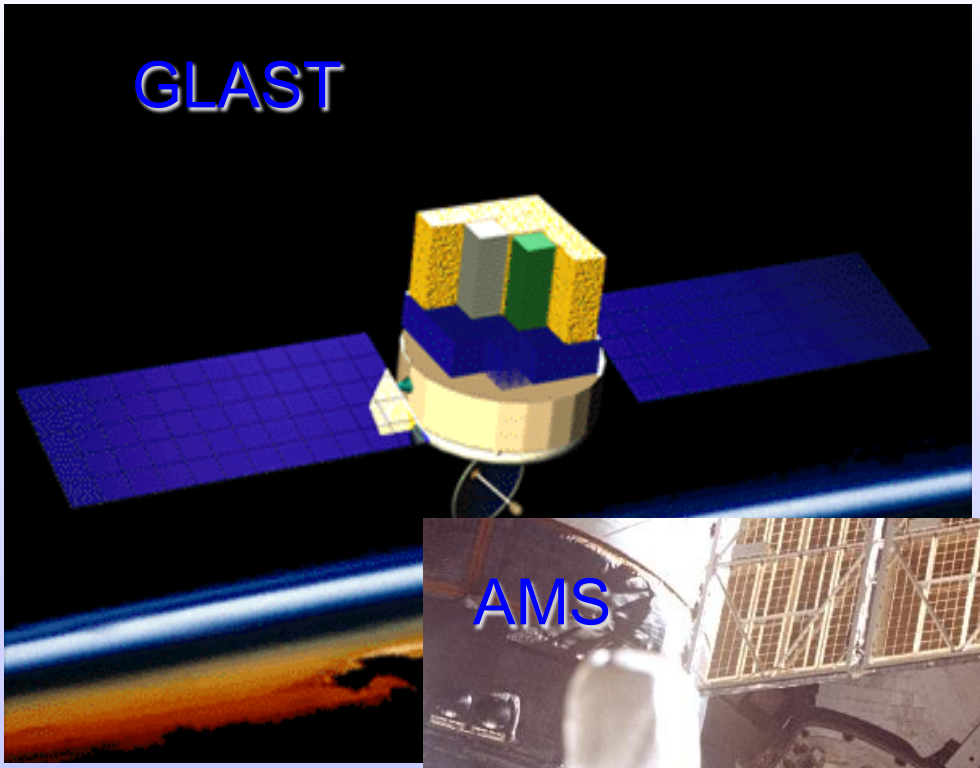
Satelliti

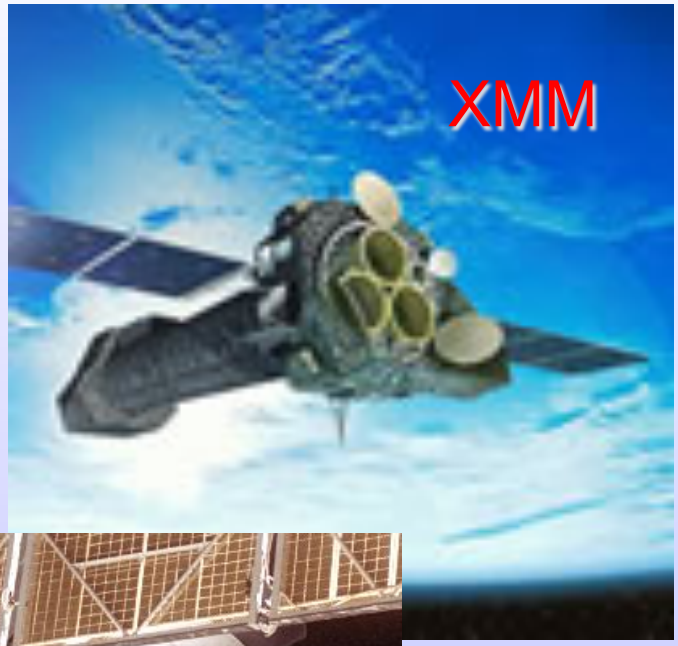
- tempo in orbita lungo
- impossibilità di recupero della strumentazione

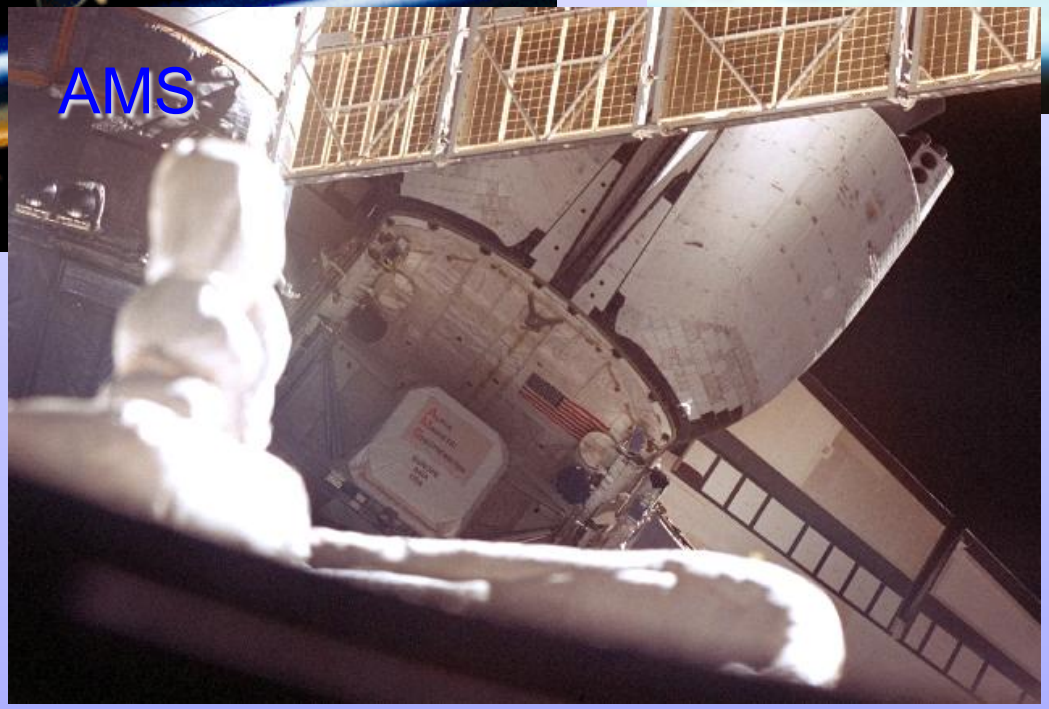
Stazione Spaziale Internazionale (ISS)

- tempo in orbita lungo
- recupero della strumentazione

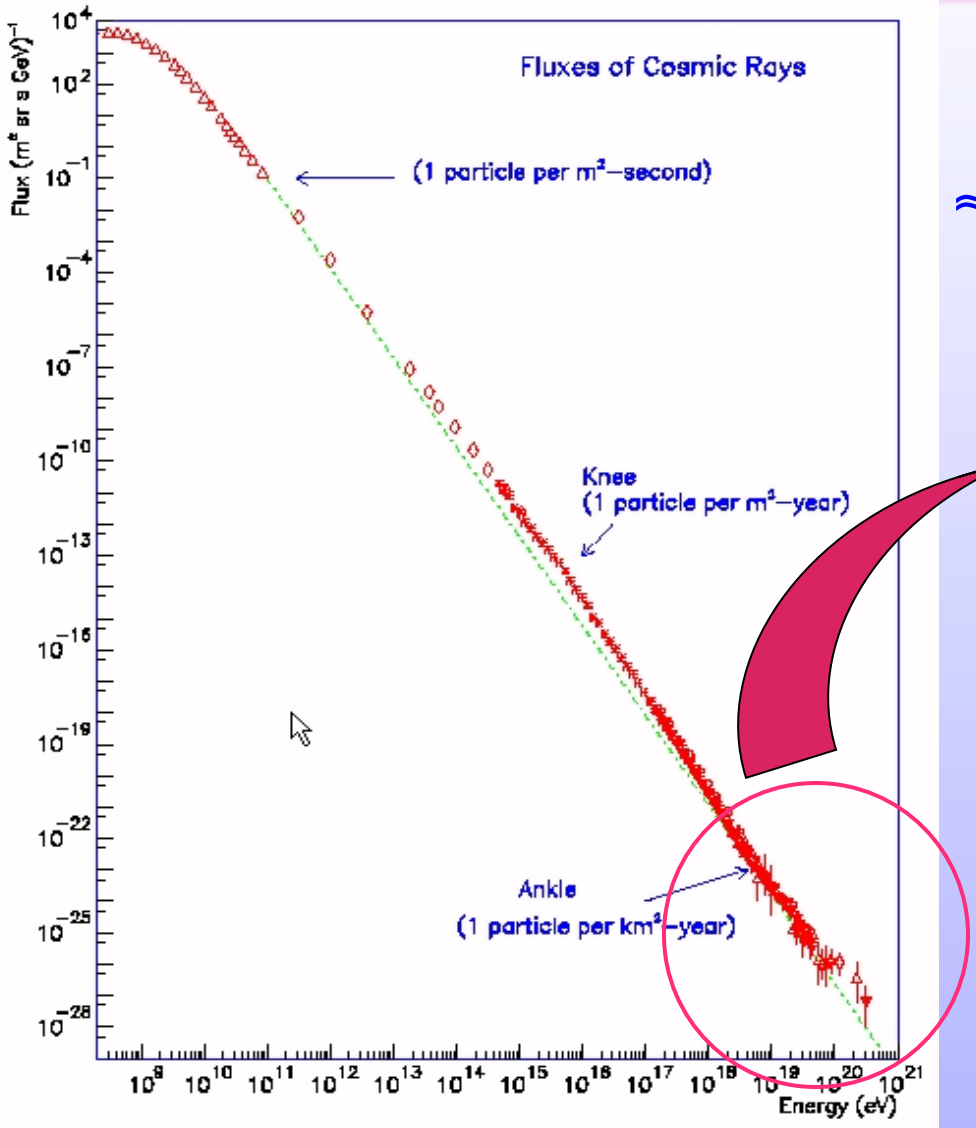
Astrofisica: XMM - GLAST – AMS







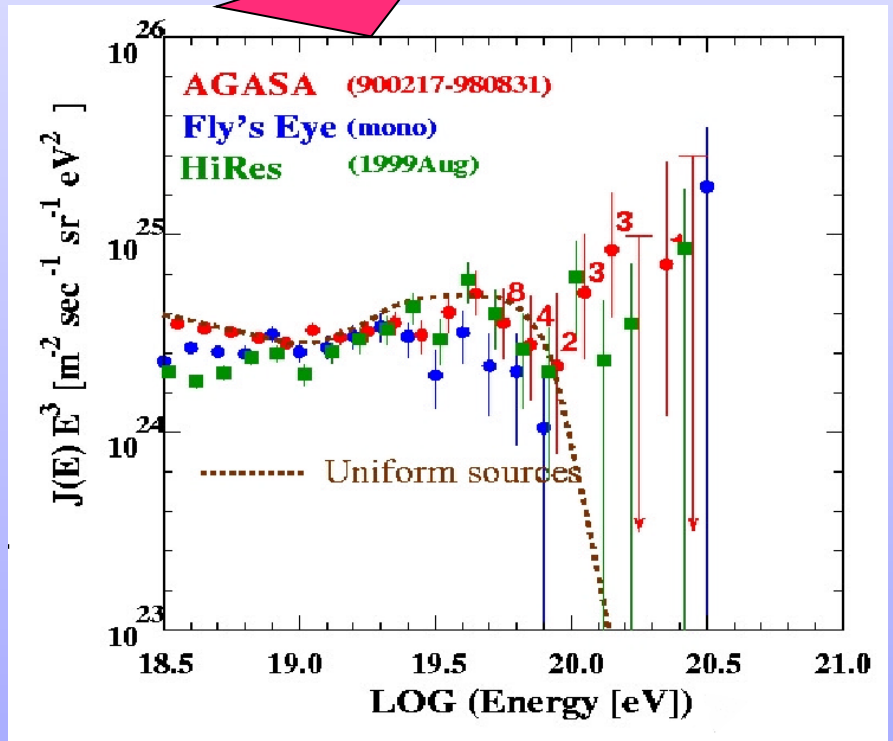
EUSO 1/2



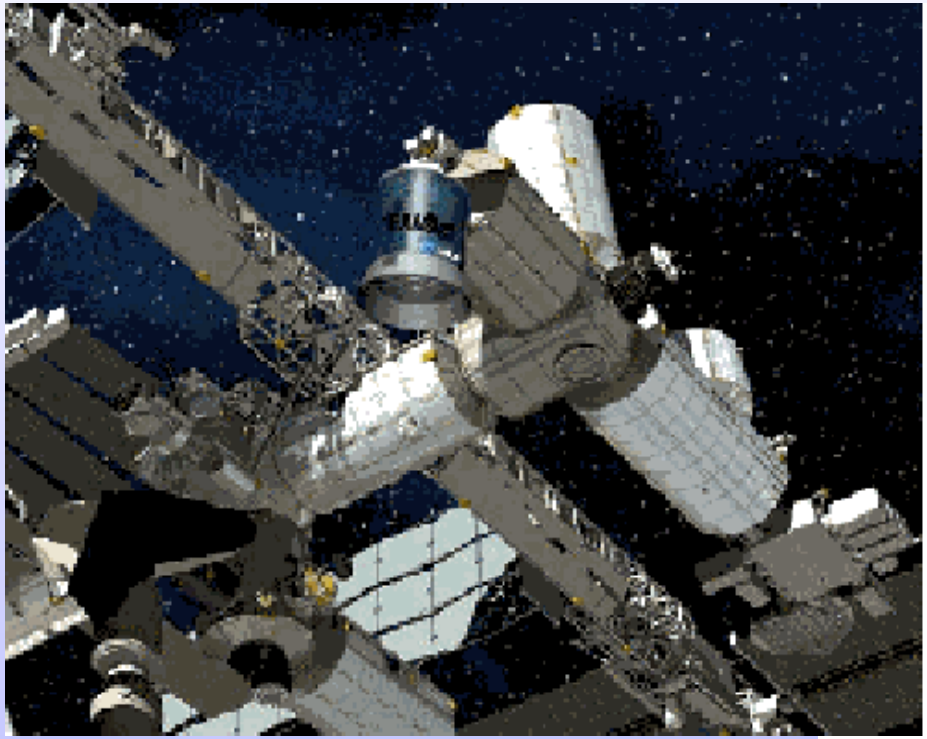
Flusso estremamente basso:
≈1 evento/sr/km^2/secolo

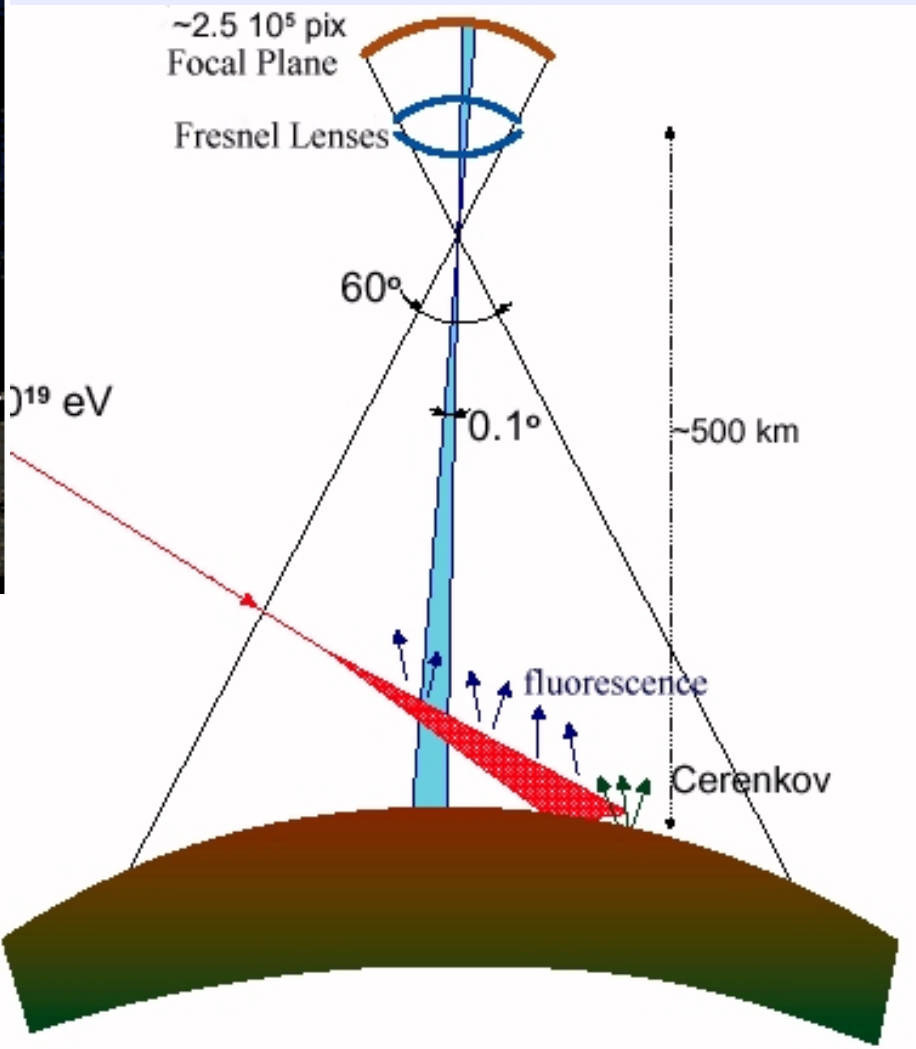
⇓

300 eventi

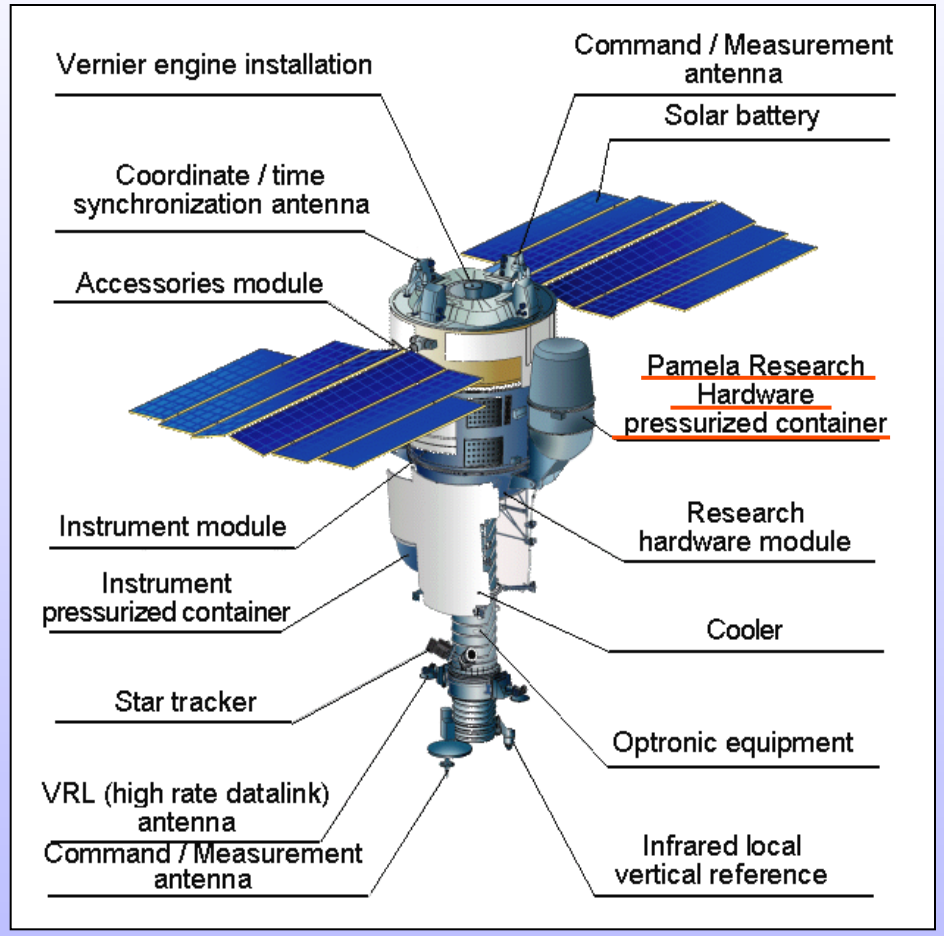


EUSO 2/2



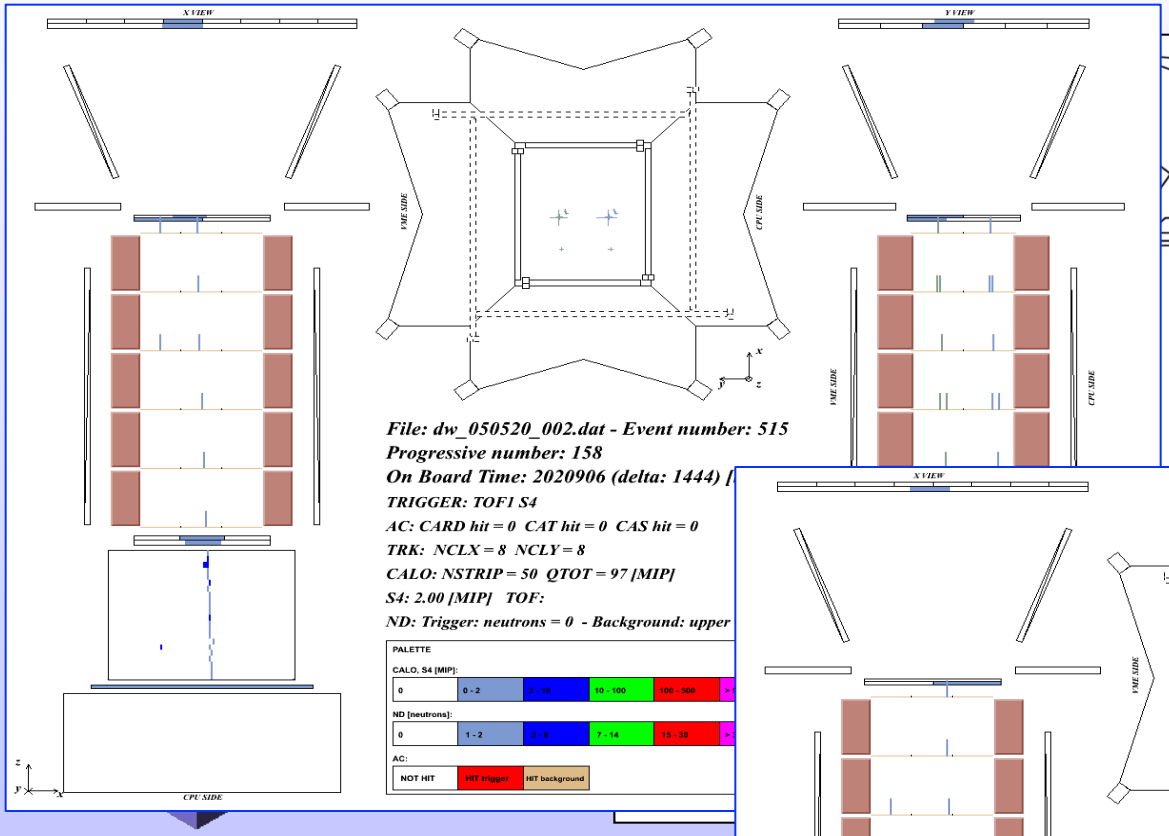

~2.5 10⁵ pix
Focal Plane
Fresnel Lenses
60°
0.1°
~500 km
fluorescence
Cerenkov

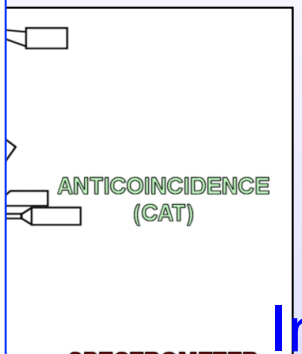
PAMELA 1/4



- Multi-spectral remote sensing of earth's surface
  - → near-real-time high-quality images
- Built by the Space factory TsSKB Progress in Samara (Russia)
- Operational orbit parameters:
  - inclination ~70°
  - altitude ~ 360-600 km (elliptical)
- Mass: 6.7 tons
- Active life >3 years
- Data transmitted via Very high-speed Radio Link (VRL)

PAMELA 2/4

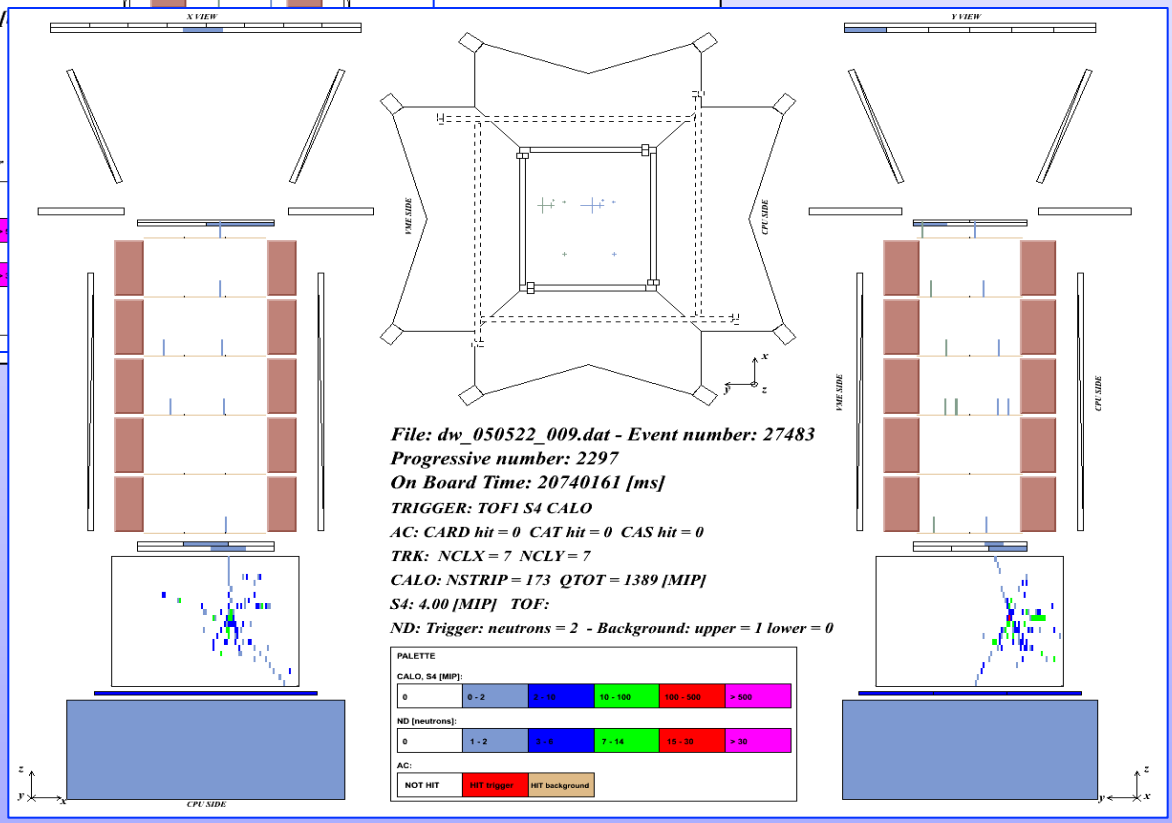




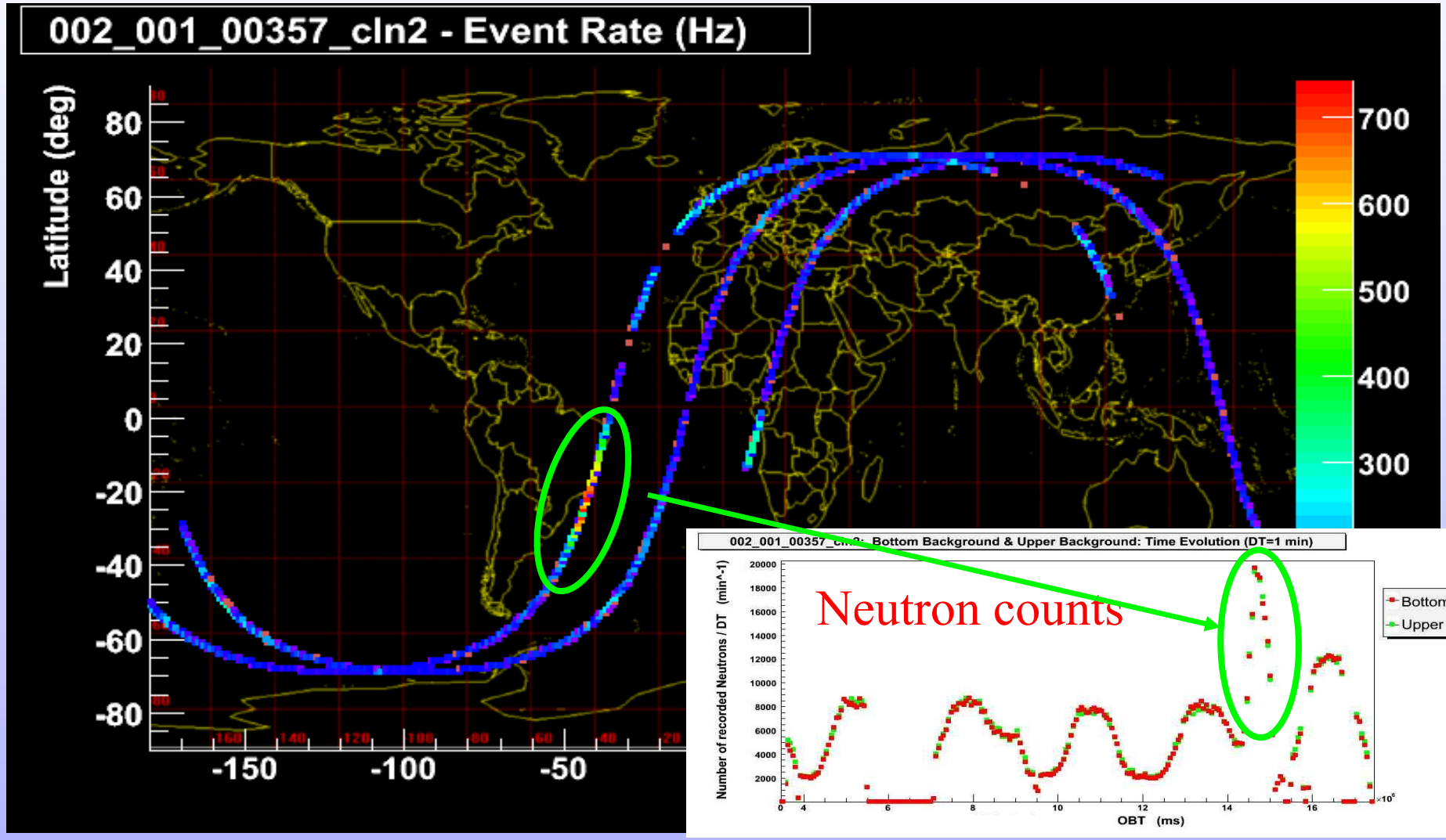
GF: 21.5 cm² sr
Mass: 470 kg
Size: 130x70x70 cm³
Power Budget: 360W

Interacting event

Non-interacting event

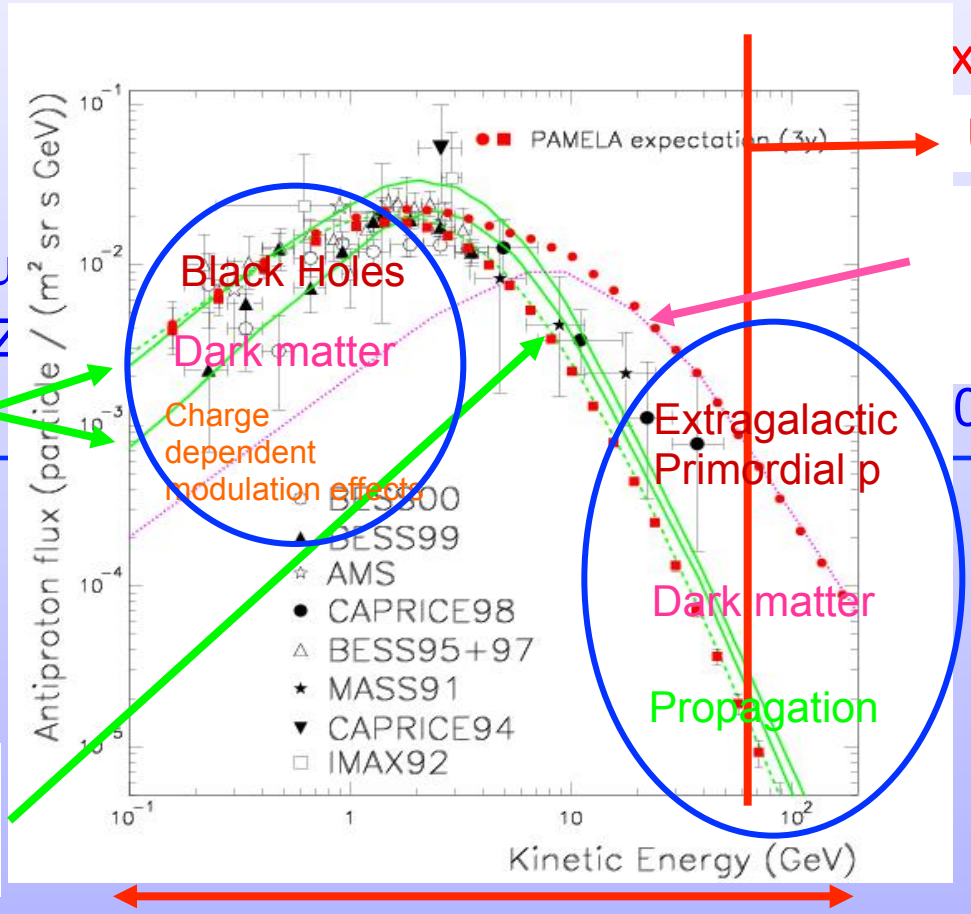


PAMELA 3/4


002_001_00357_cln2 - Event Rate (Hz)
Latitude (deg)
80
60
40
20
0
-20
-40
-60
-80
-150
-100
-50
700
600
500
400
300
Neutron counts
Bottom Background & Upper Background: Time Evolution (DT=1 min)
Number of recorded Neutrons / DT (min^-1)
OBT (ms)
Bottom
Upper

PAMELA 4/4

	energy range	particles/3 years
Antiproton flux	80 MeV - 190 GeV	~3×10^4
Positron flux		$\times10^5$
Electron flux		
Proton flux		
Electron/positron flu		
Light Nuclei (up to Z		0^{-7} in He/He)



Unexplored Region

Primary production from $\chi\chi$ annihilation ($m(\chi)$ = 964 GeV)

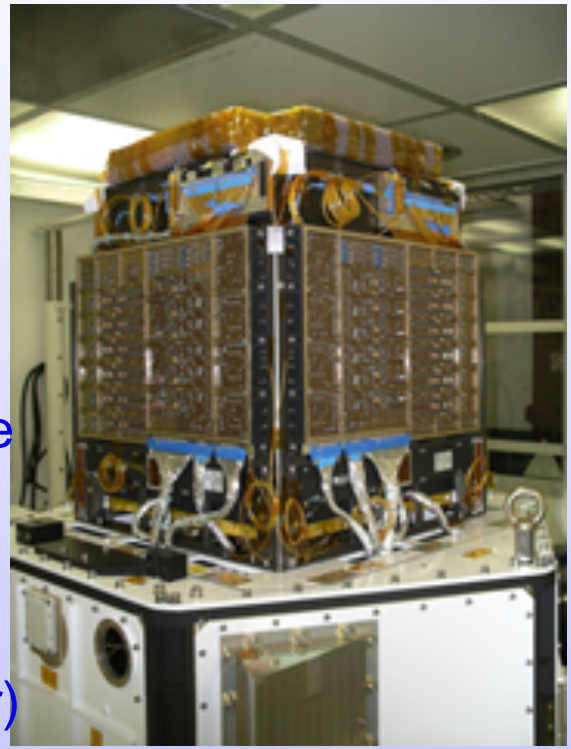
Secondary production (upper and lower limits) Simon et al.

Secondary production (CAPRICE94-based) Bergström et al.

PAMELA energy range

AGILE 1/2

Astrorivelatore Gamma Immagini LEggero

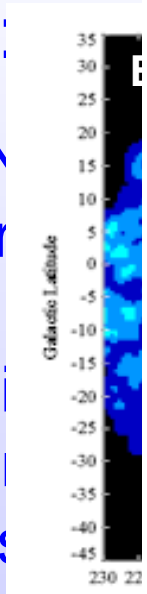


- Missione dedicata all'astrofisica gamma
- Optimal imaging capabilities in both the gamma-ray energy range (30 MeV-30 GeV) and hard X-ray range (15-60 keV)
- Scientific Team: researchers and engineers of INAF-IASF, INFN, and several Italian Universities. The project is headed by M. Tavani (Principal Investigator) and G. Barbiellini (Co-Principal Investigator)
- Participation of several leading companies from the Italian space industry, including CARLO GAVAZZI SPACE, ALCATEL-ALENIA Space LABEN, OERLIKON-CONTRAVES Space, TELESPAZIO, and MIPOT

AGILE 2/2

Major topics are:

- Active Galactic N
- Gamma Ray Bur
- Pulsars
- Gamma-Ray Uni
- Supernova Rem
- Compact Object
- Gamma-ray Diffuse E
- TeV Sources
- Fundamental Physics



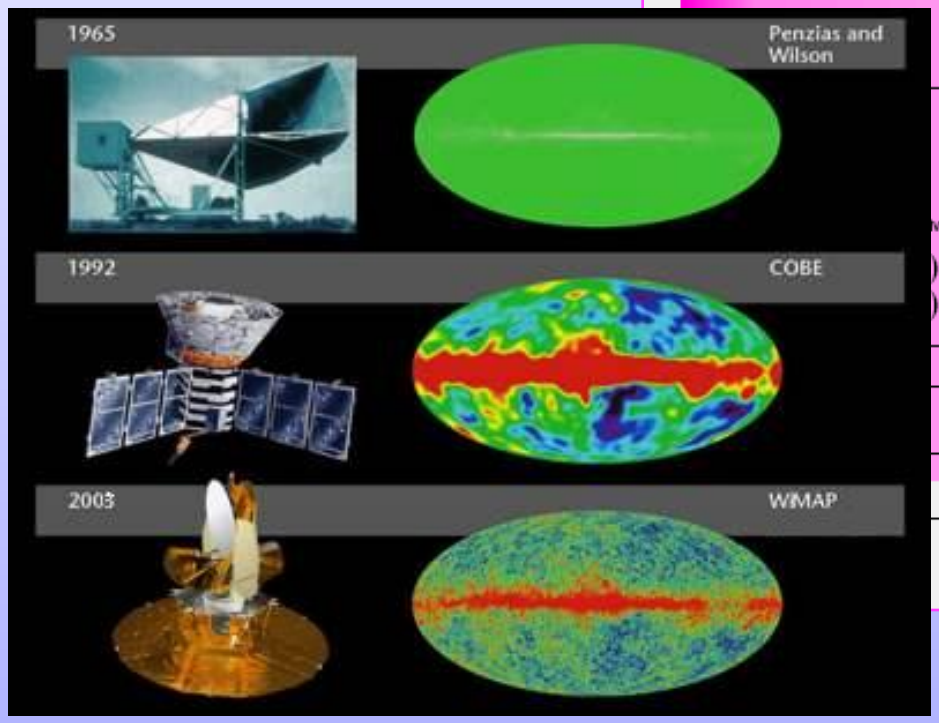
Gamma-ray Imaging Detector (GRID)		
Energy Range	30 MeV – 50 GeV	
Field of view	~ 3 sr	
Sensitivity at 100 MeV (ph cm^{-2} s^{-1} MeV^{-1})	6×10^{-9}	(5σ in 10^6 s)
Sensitivity at 1 GeV (ph cm^{-2} s^{-1} MeV^{-1})	4×10^{-11}	(5σ in 10^6 s)
Angular Resolution at 1 GeV	36 arcmin	(68% cont. radius)
Source Location Accuracy	~5–20 arcmin	S/N~10
Energy Resolution	$\Delta E/E\sim1$	at 300 MeV
Absolute Time Resolution	$\sim 1\,\mu$s	
Deadtime	$\sim 200\,\mu$s	
Hard X–ray Imaging Detector (Super-AGILE)		
Energy Range	10 – 40 keV	
Field of view	107°×68°	FW at Zero Sens.
Sensitivity (at 15 keV)	~5 mCrab	(5σ in 1 day)
Angular Resolution (pixel size)	~ 6 arcmin	
Source Location Accuracy	~2-3 arcmin	S/N~10
Energy Resolution	$\Delta E<4$ keV	
Absolute Time Resolution	$\sim 4\,\mu$s	
Deadtime (for each of the 16 readout units)	$\sim 4\,\mu$s	
Mini-Calorimeter		
Energy Range	0.3 – 200 MeV	
Energy Resolution	~ 1 MeV	above 1 MeV
Absolute Time Resolution	$\sim 3\,\mu$s	
Deadtime (for each of the 30 CsI bars)	$\sim 20\,\mu$s	

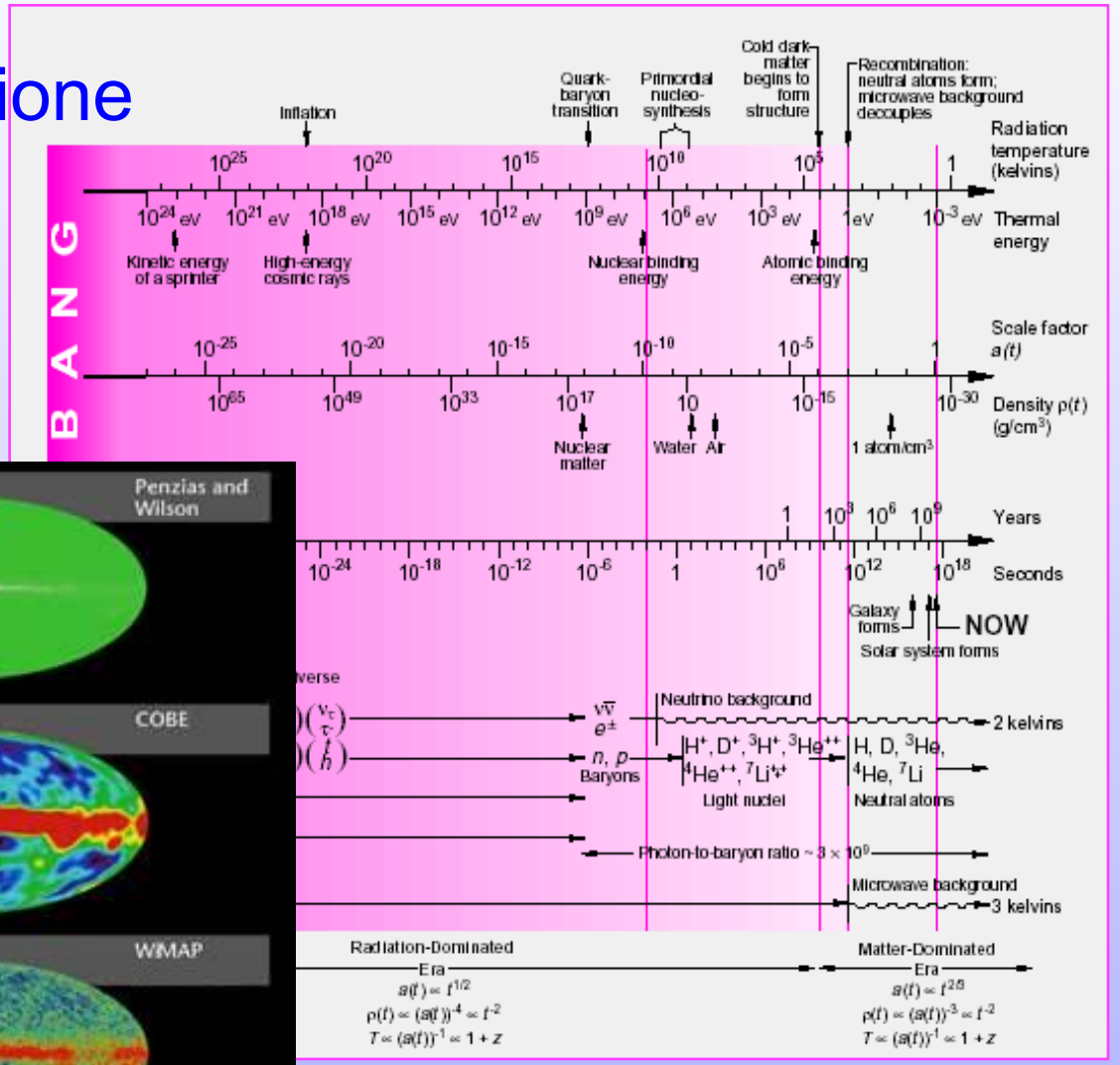
AGILE was successfully launched on April 23, 2007 by the Indian PSLV-C8 rocket from the Sriharikota base (Chennai-Madras).

The AGILE satellite was injected in the nominal equatorial orbit in agreement with the Scientific Requirements of the Mission. The satellite was tracked during its first pass over the ASI Malindi ground station in Kenya on Apr. 23rd. During its first orbit, its radio signal was also independently detected from the Sriharikota and Bangalore ground stations. The satellite is now in the initial Commissioning Phase. All test results are nominal.

PLANCK 1/3

Fondo di Radiazione

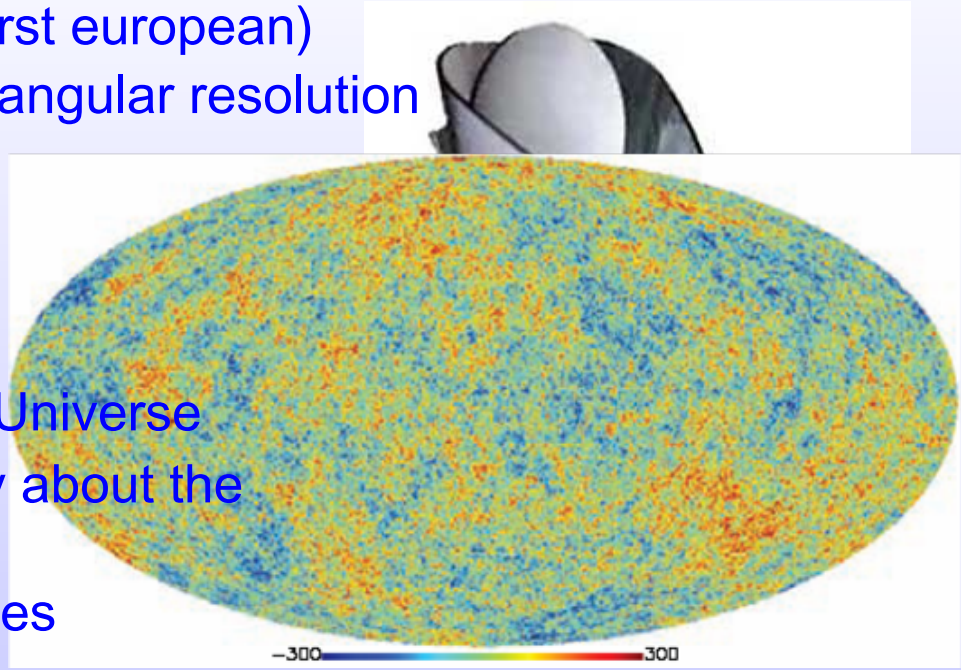




PLANCK 2/3

Planck is the third mission on CMB (first european)

- Better sensitivity ($\Delta T/T \sim 2 \times 10^{-6}$) and angular resolution (up to 5')
- Wider frequency range



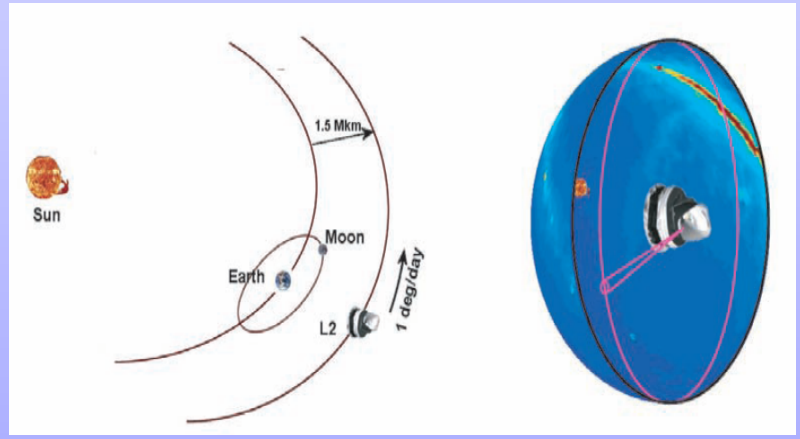
Main scientific Objectives:

- Determination of geometry of the Universe
- Determination of the correct theory about the Universe origin and evolution
- Complete map of CMB anisotrophies

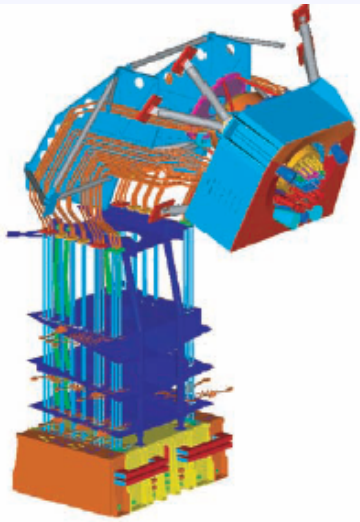
Orbit: Lissajous around Lagrangian point L2 of Earth-Sun-Moon system

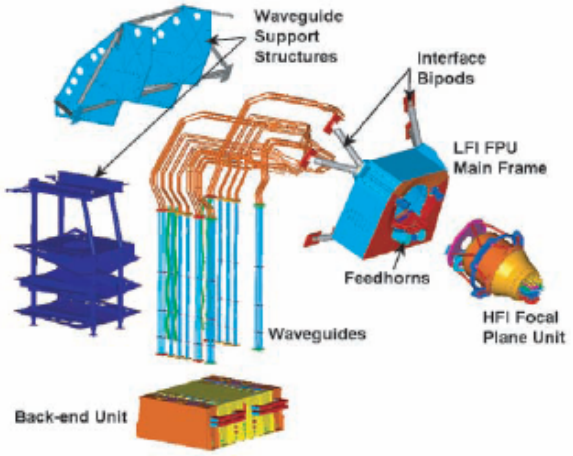
Distance from the Earth: 1.5 x 10^6 km

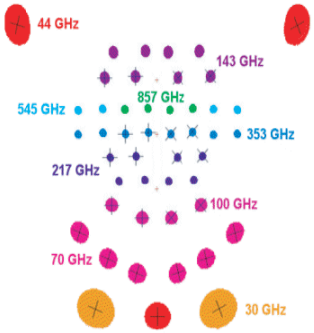
Spin axis: opposite direction respect to the Sun

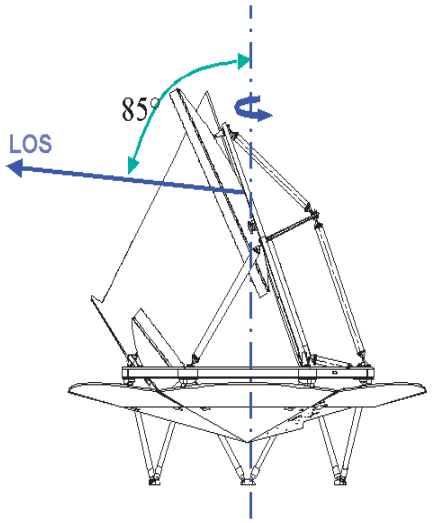


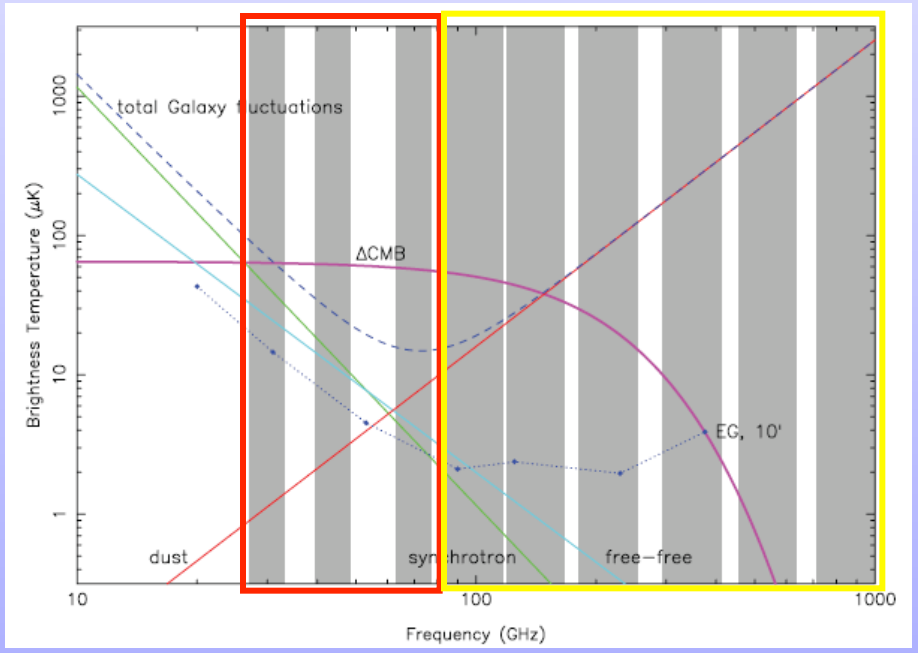
PLANCK 3/3







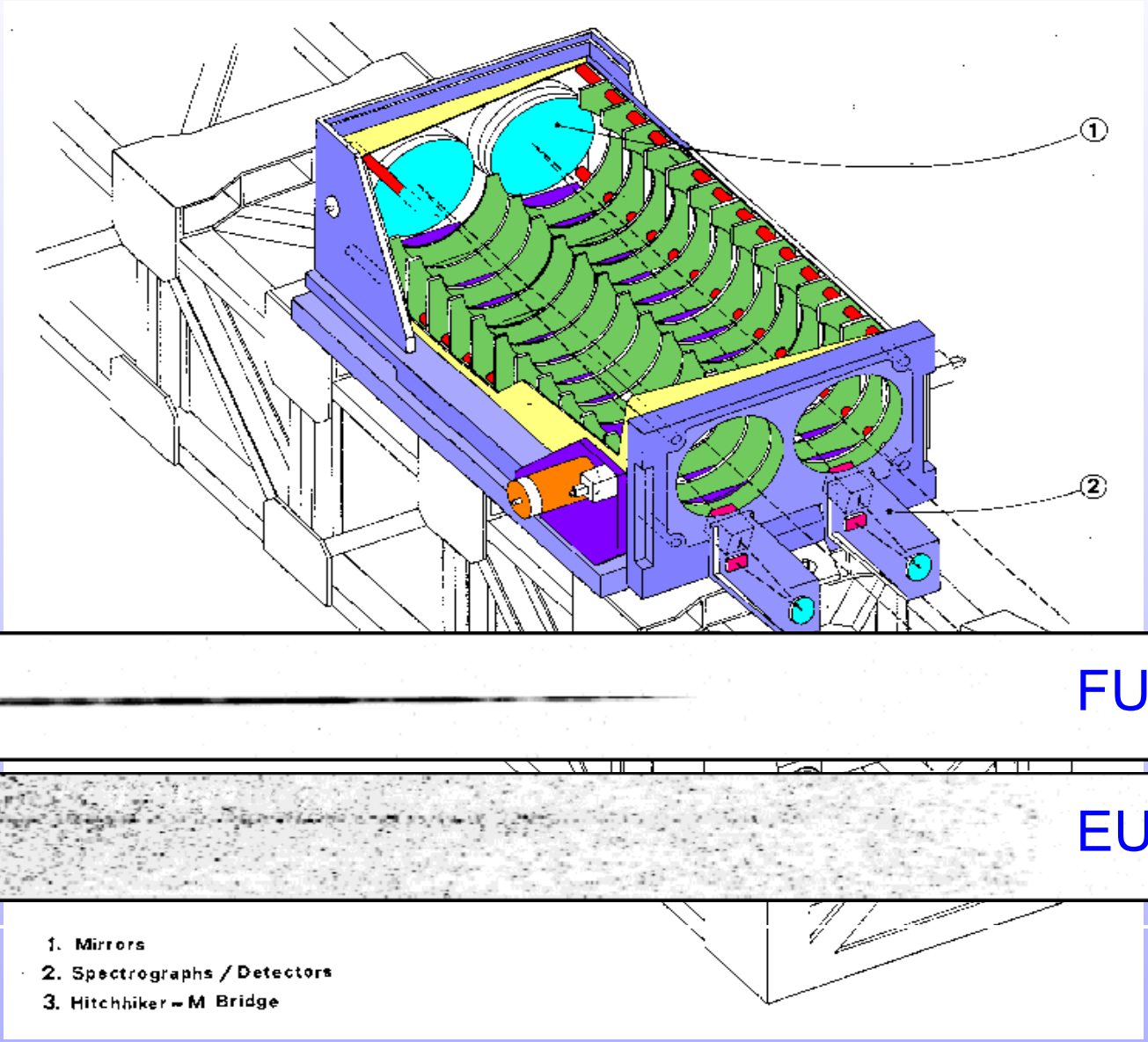




Centre frequency (GHz)	30	44	70
Bandwidth (GHz)	6	8.8	14
Angular resolution (arcminutes, FWHM)	33	24	14
Detector temperature (K)	20 K		
ΔT/T Intensity [10^{-6} μK/K]	2.0	2.7	4.7
ΔT/T polarization [μK/K]	2.8	3.9	6.7

Astronomia: Hubble

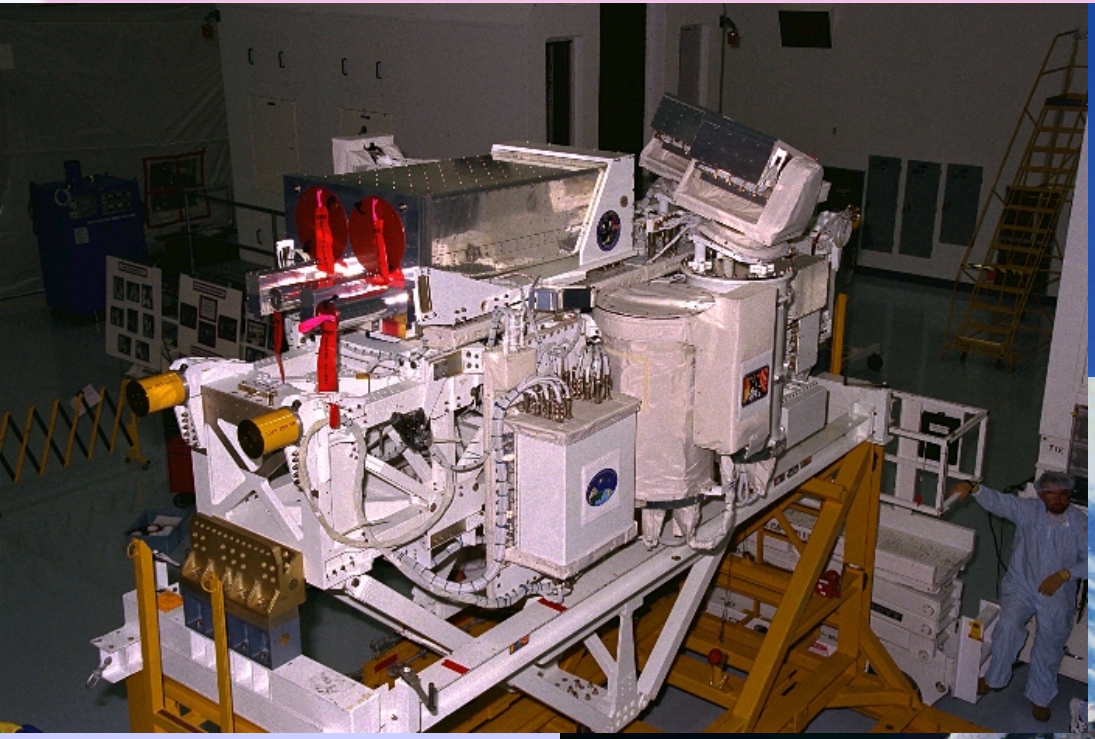
Astronomia: UVSTAR 1/4

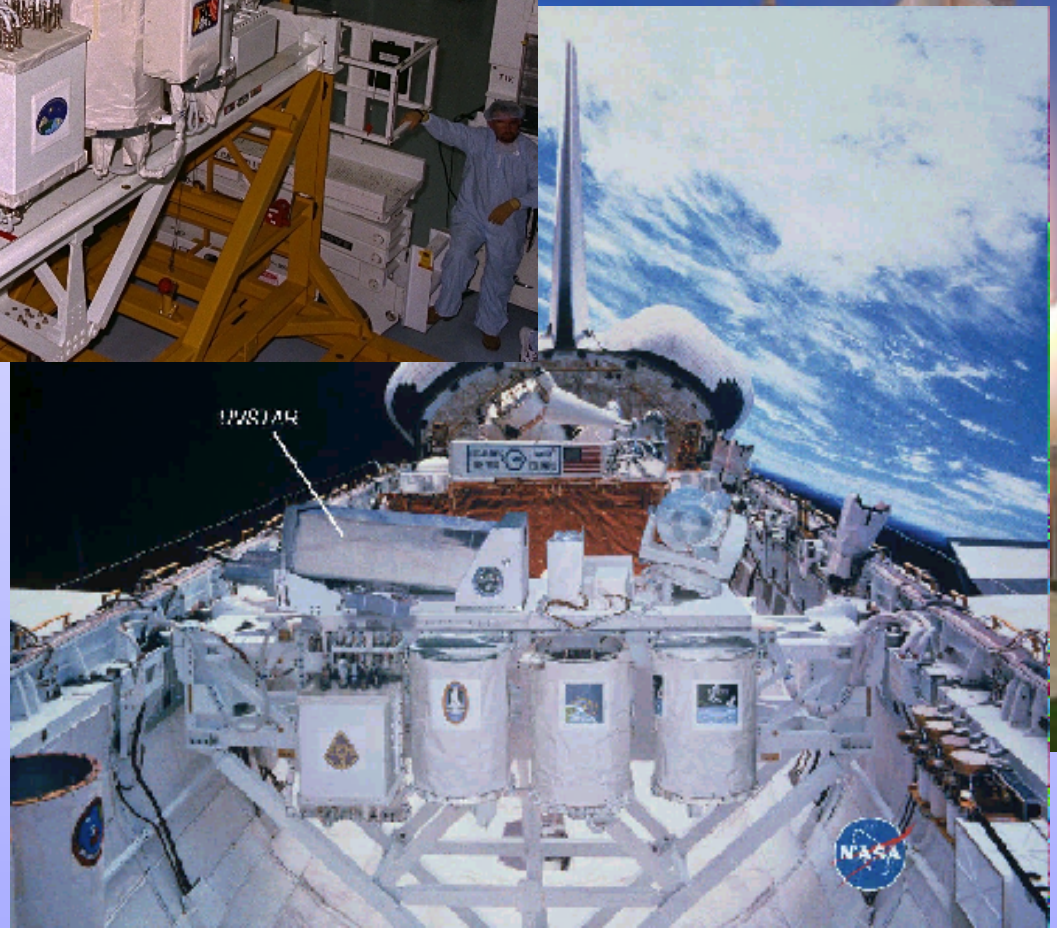


spazio

Lunghezza d'onda

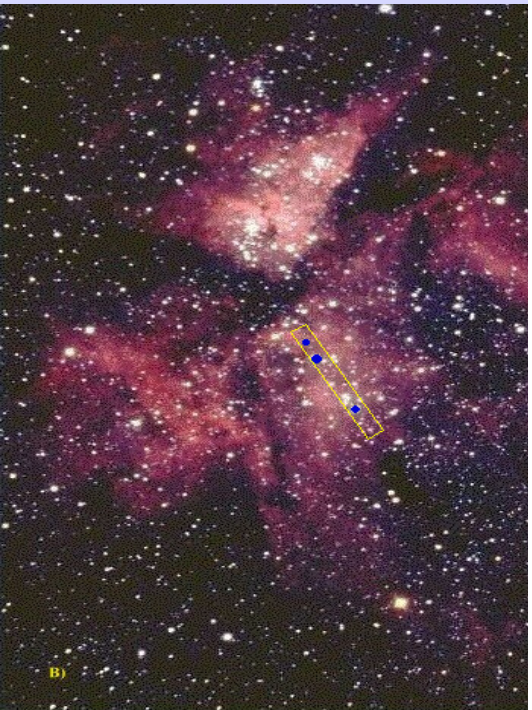
Astronomia: UVSTAR 2/4

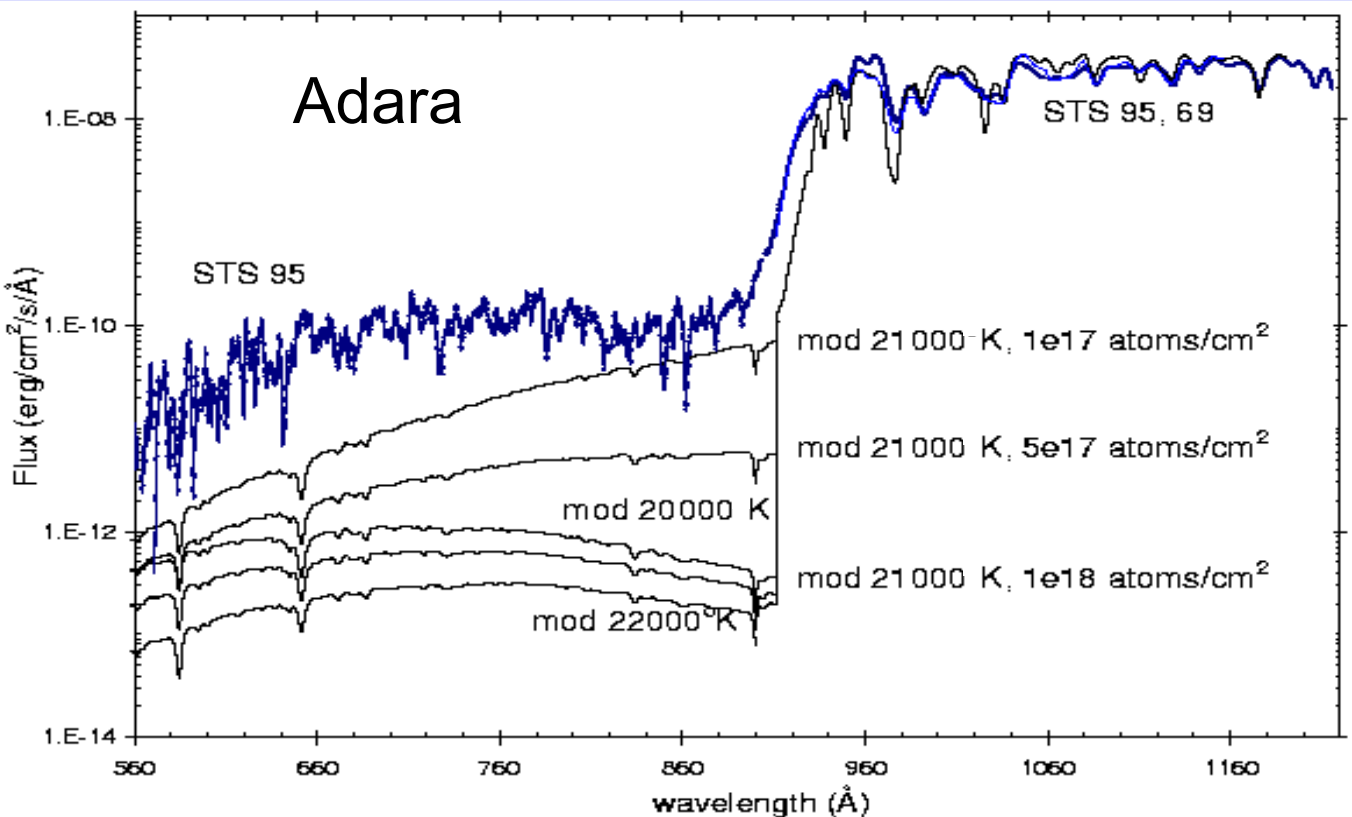




Astronomia: UVSTAR 3/4

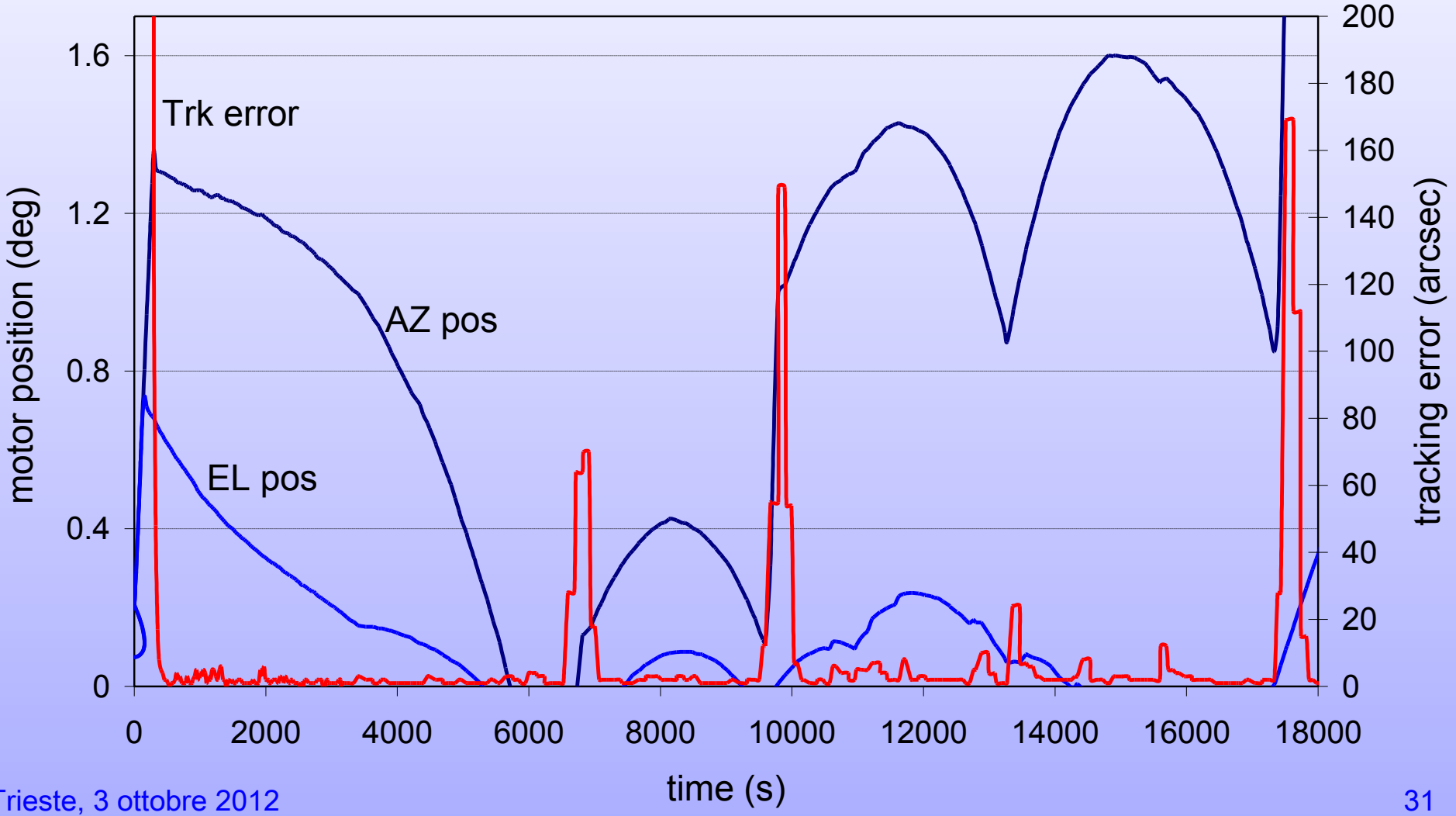
- sistema di movimentazione autonomo munito di 2 telescopi ausiliari per la direzione di puntamento
- osserva atmosfere stellari, regioni HII, anelli di IO, comete
- analisi spettrale del flusso nelle varie componenti UV (FUV/EUV)



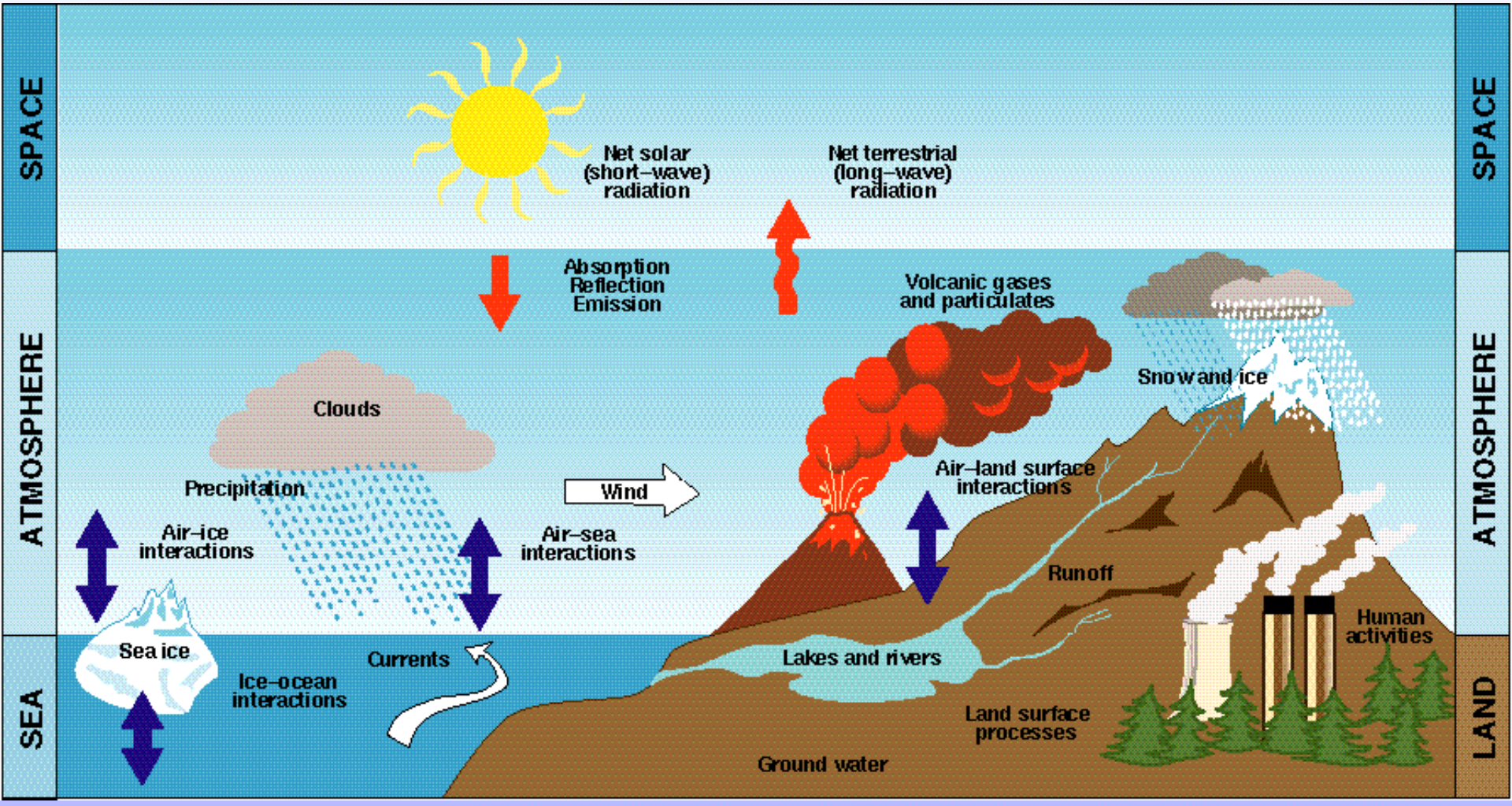


Astronomia: UVSTAR 4/4

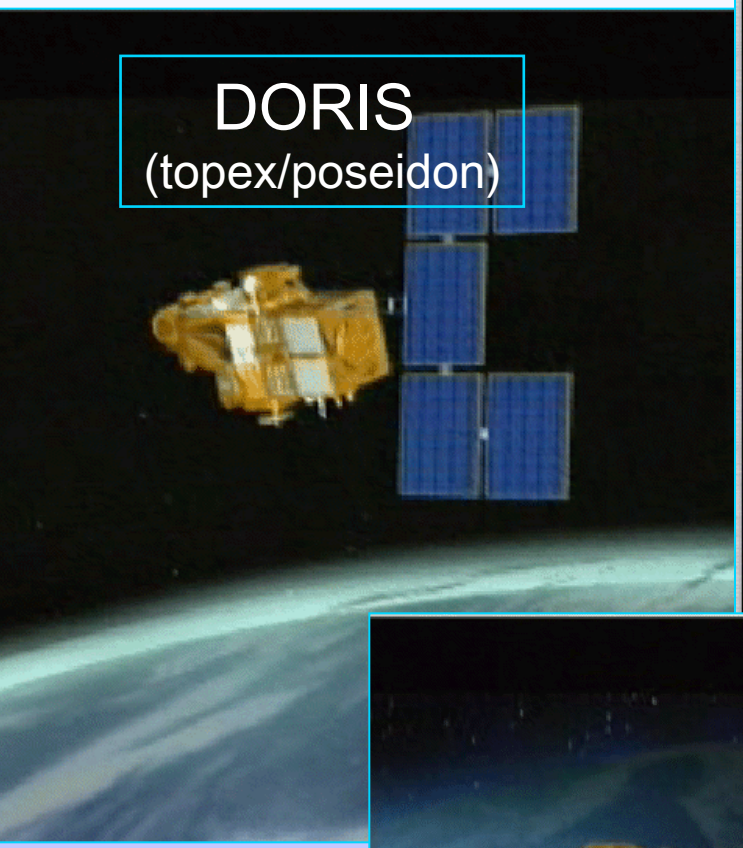
Risultati tecnologici: sistema di puntamento

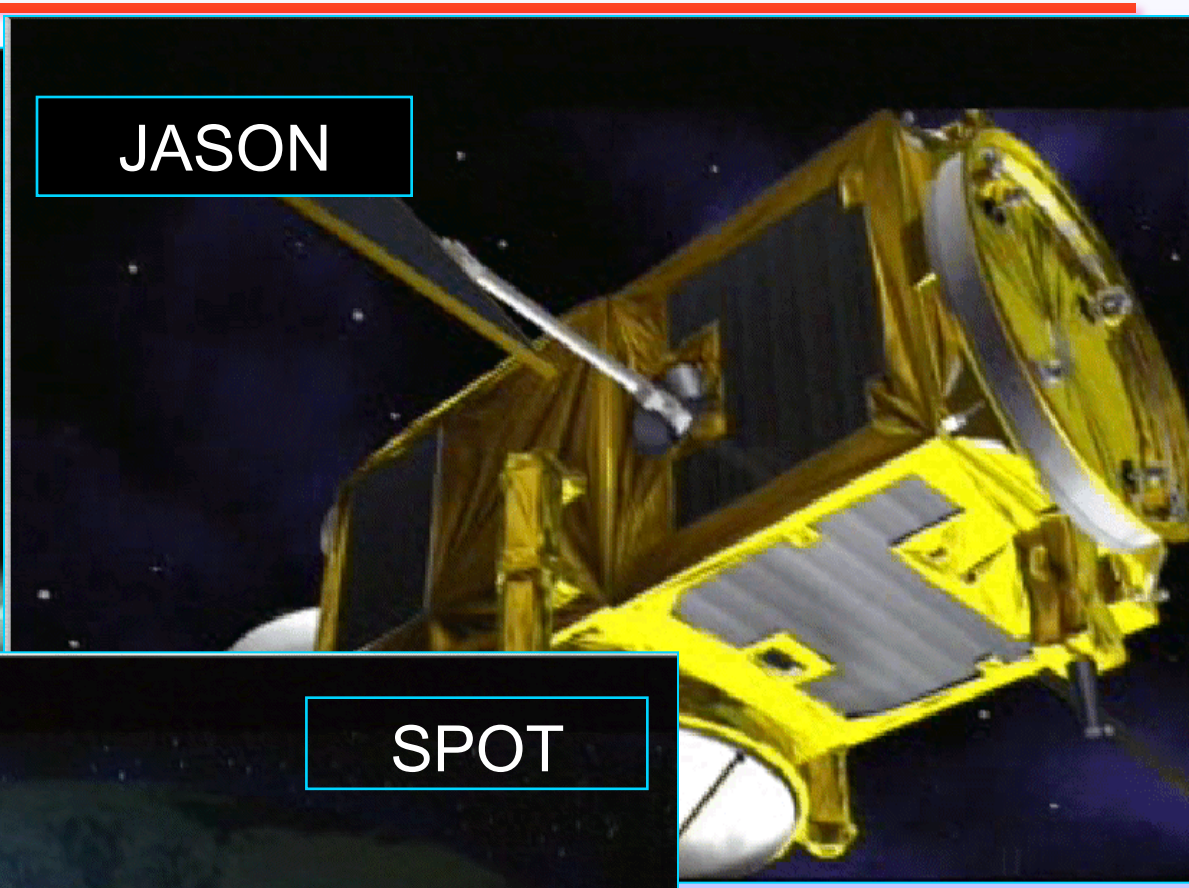


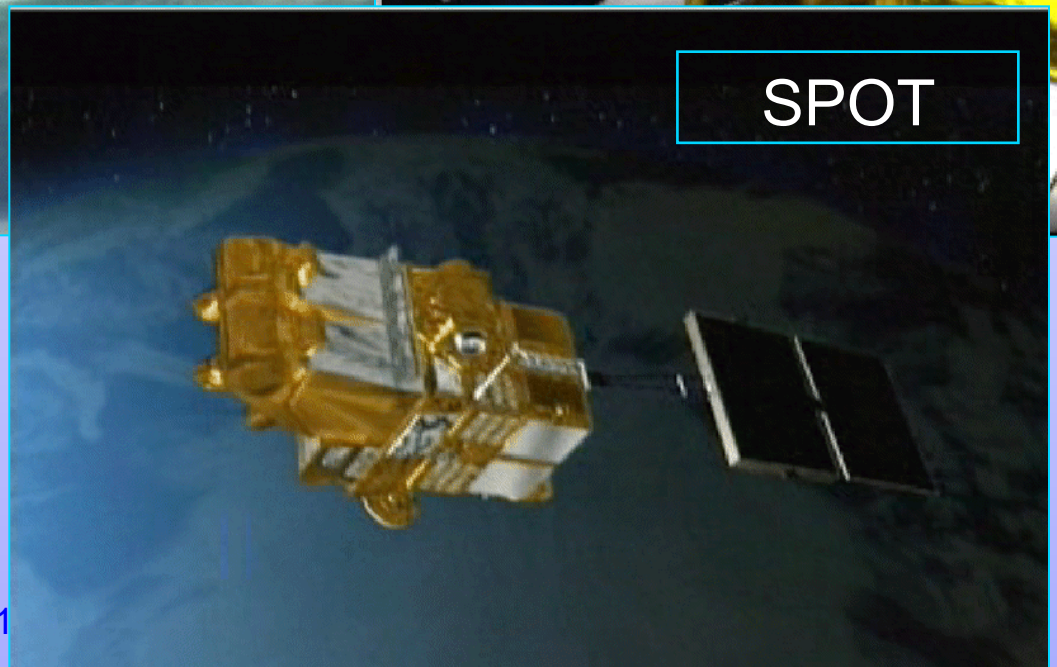
Fisica della Terra



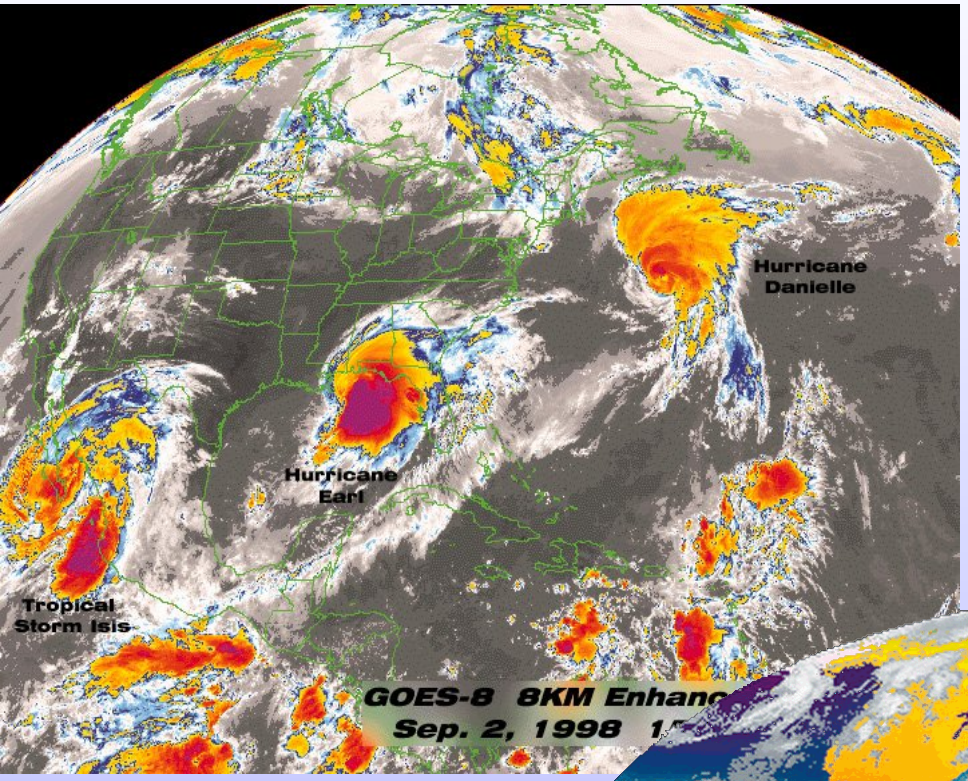
Osservazioni della Terra

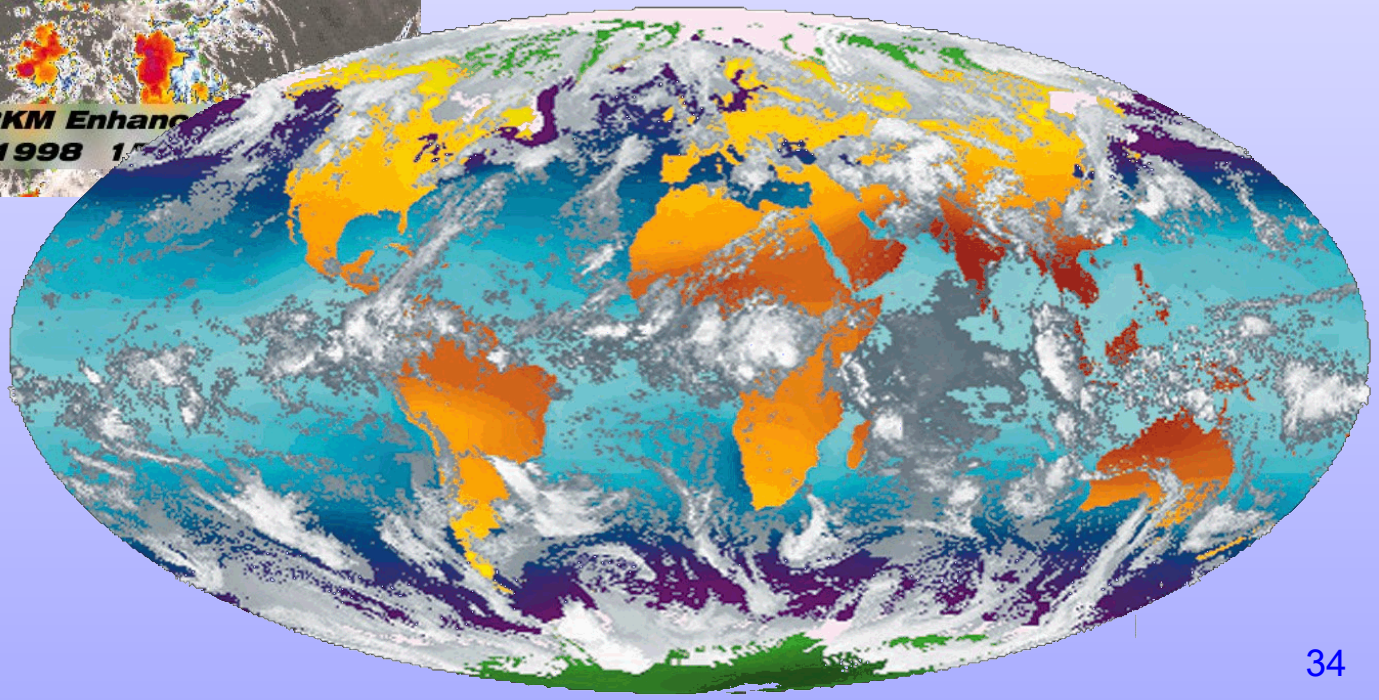




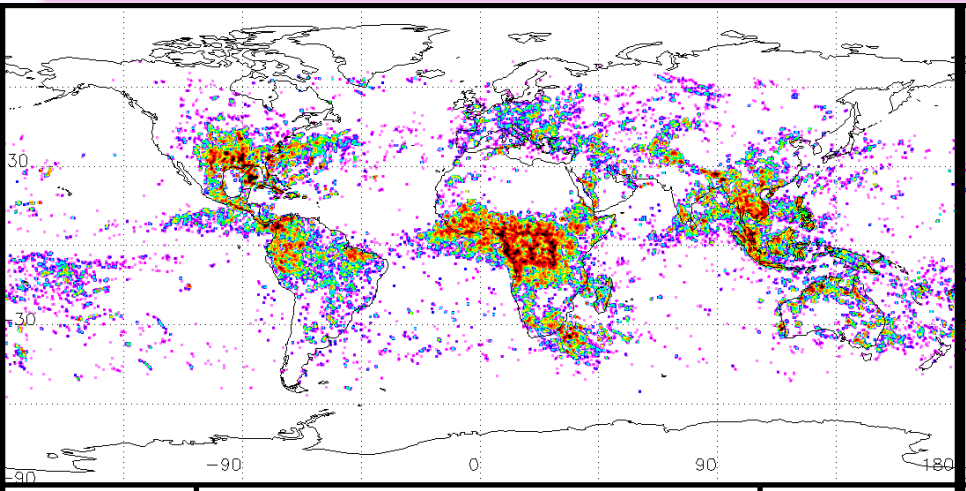


Metereologia





Metereologia

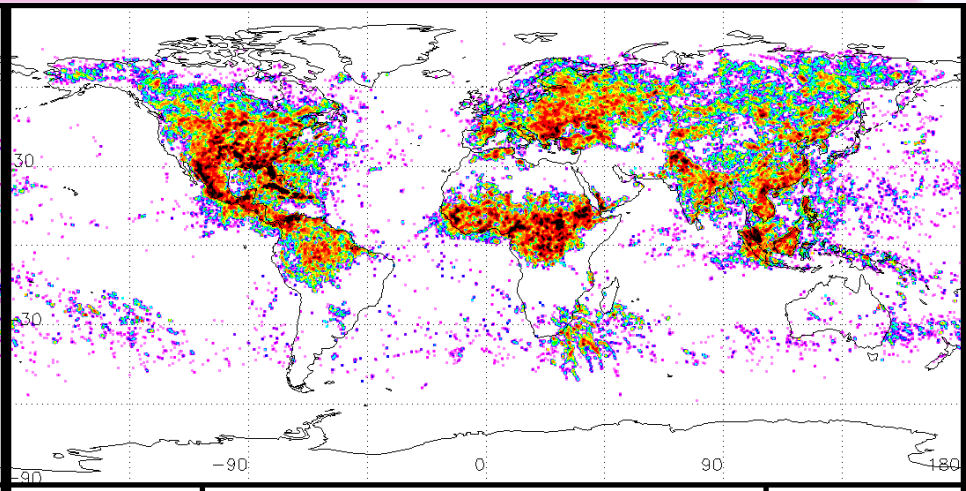


Orbits 710
Areas 27718
Flashes 151705
Groups 771976
Events 1619345
(Created : 02/15/100)

1 2 3 4 5 >5 >10 >15 >25 >50 >100 >150
Flash scale

1999 March, April, May

OPTICAL TRANSIENT DETECTOR
NASA / MSFC



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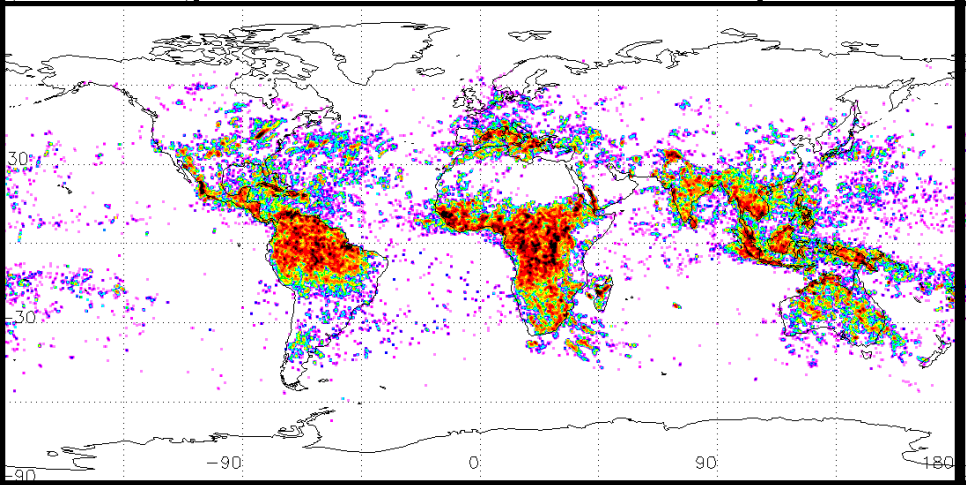
Flash scale

1999 June, July, August

OPTICAL TRANSIENT DETECTOR
NASA / MSFC



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Flashes 229678
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Events 2454938
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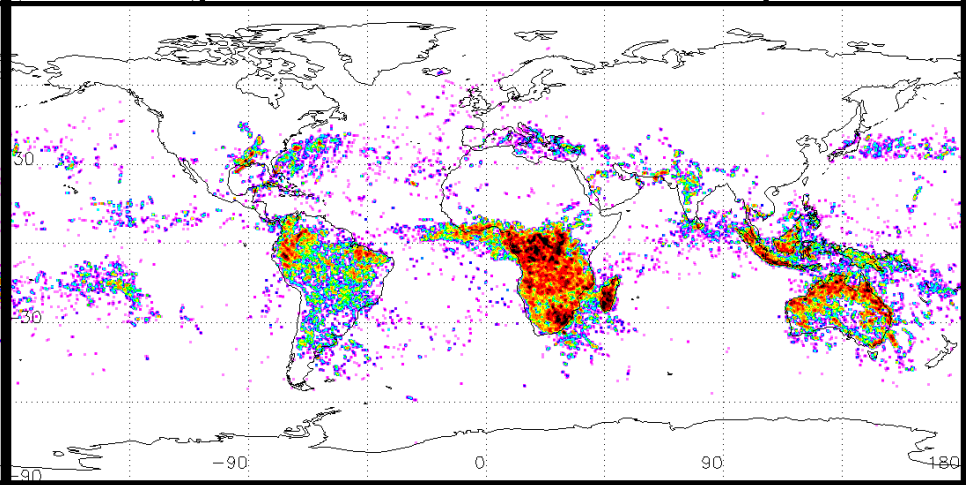
Flash scale

1999 September, October, November

OPTICAL TRANSIENT DETECTOR
NASA / MSFC



Orbits 799
Areas 27117
Flashes 137810
Groups 683597
Events 1463457
(Created : 02/14/100)

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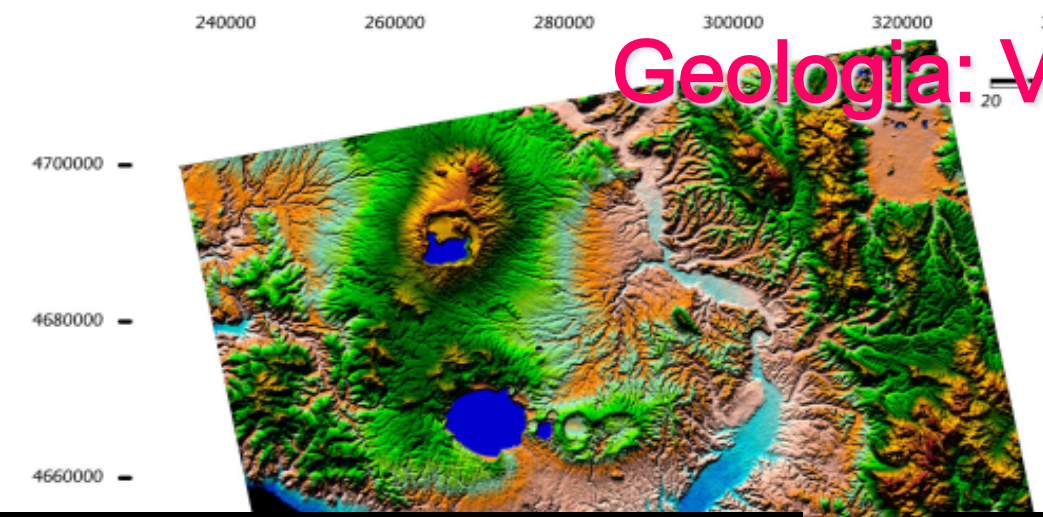
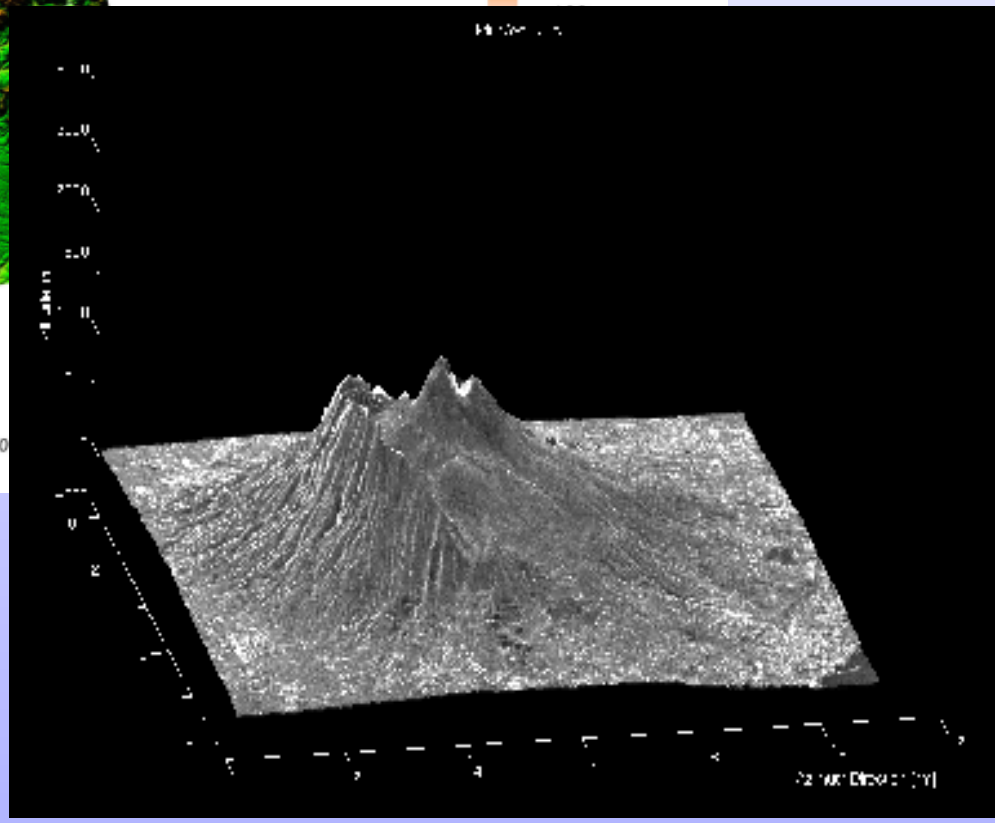
Flash scale

1998 December, 1999 January, 1999 February

OPTICAL TRANSIENT DETECTOR
NASA / MSFC

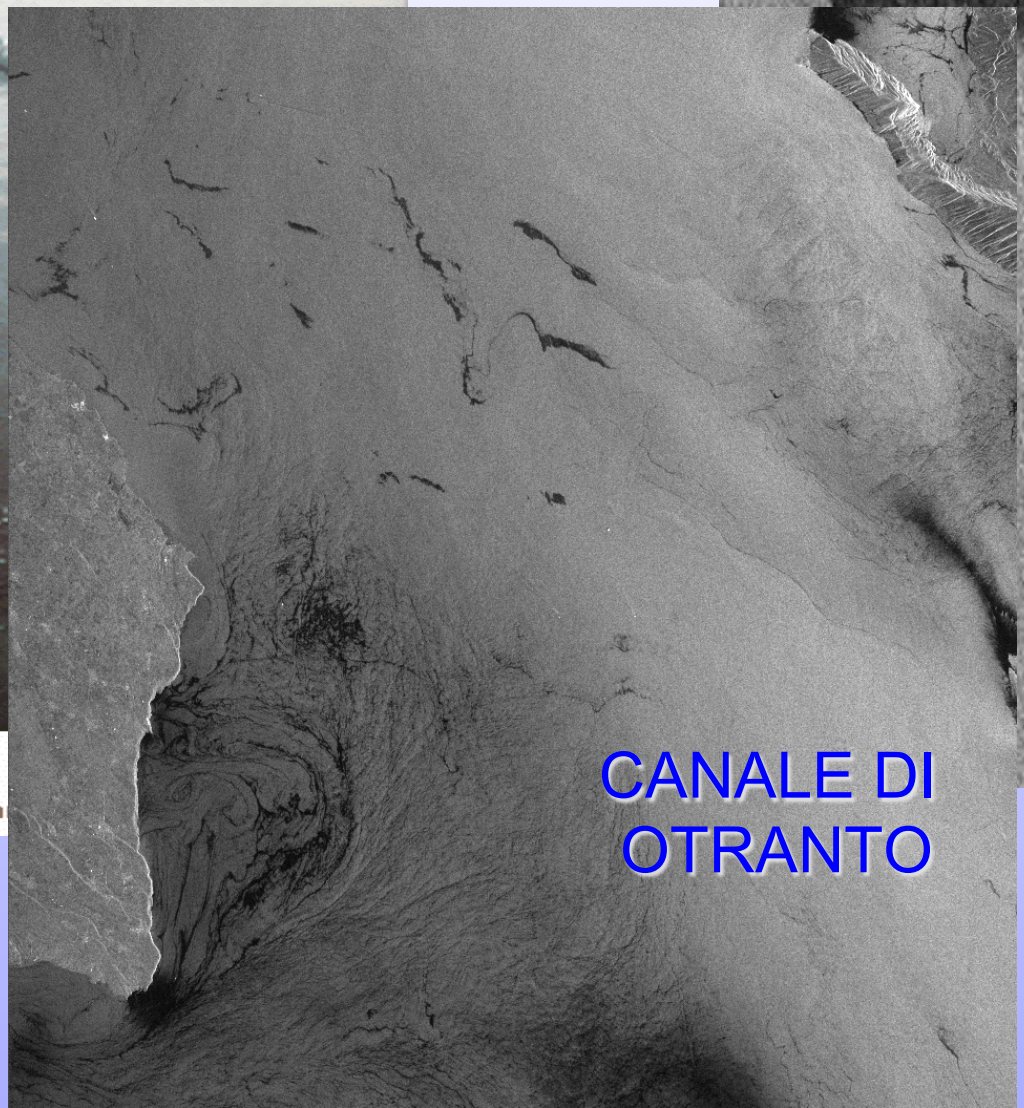
Geologia: Vesuvio



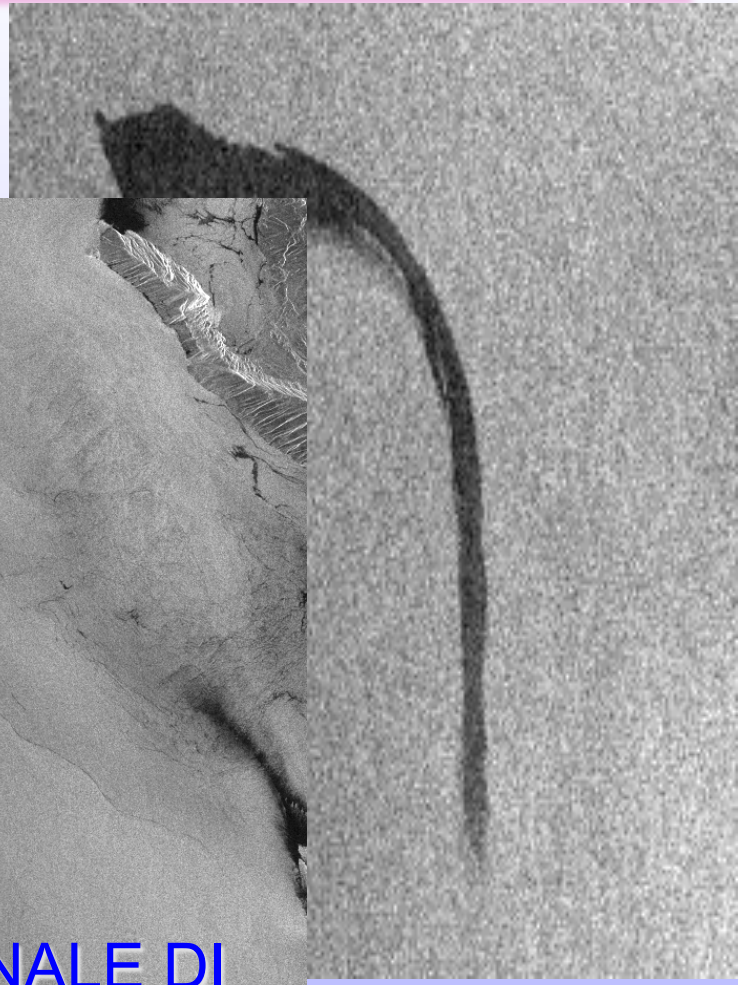


Ambiente: Inquinamento

Thames Water Authority dump sewage in the North Sea. Copyright Greenpeace / Morga



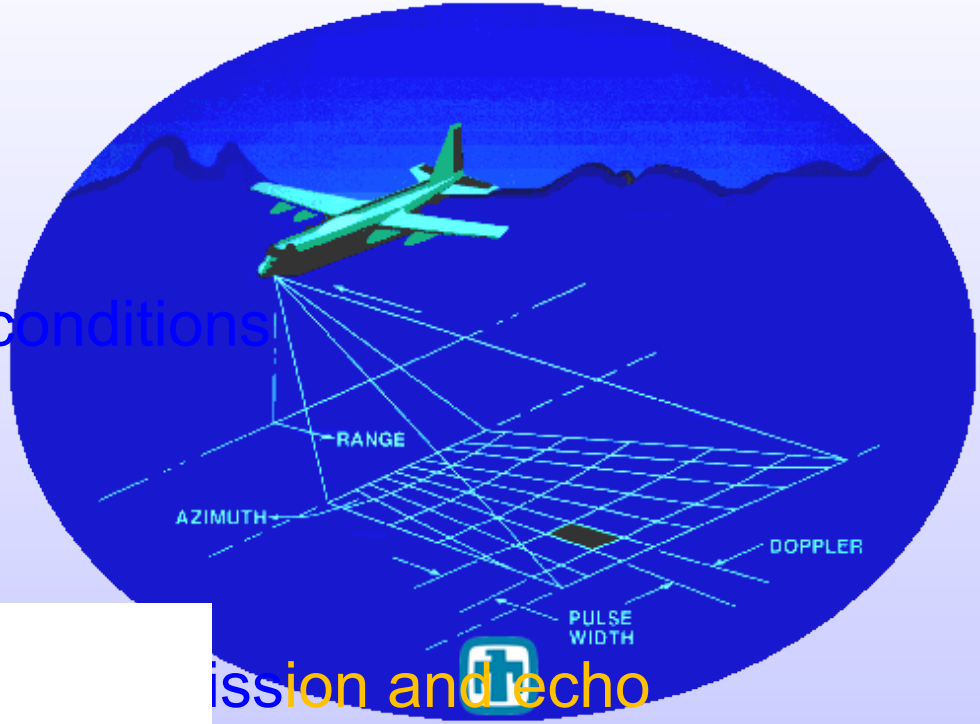
CANALE DI OTRANTO



Synthetic Aperture Radar - SAR

Radio Signals

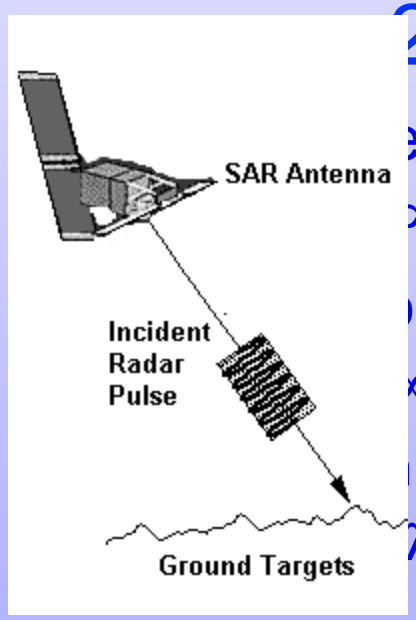
- Long range propagation characteristics
- Reduced effect of weather conditions
- Unique response of terrain

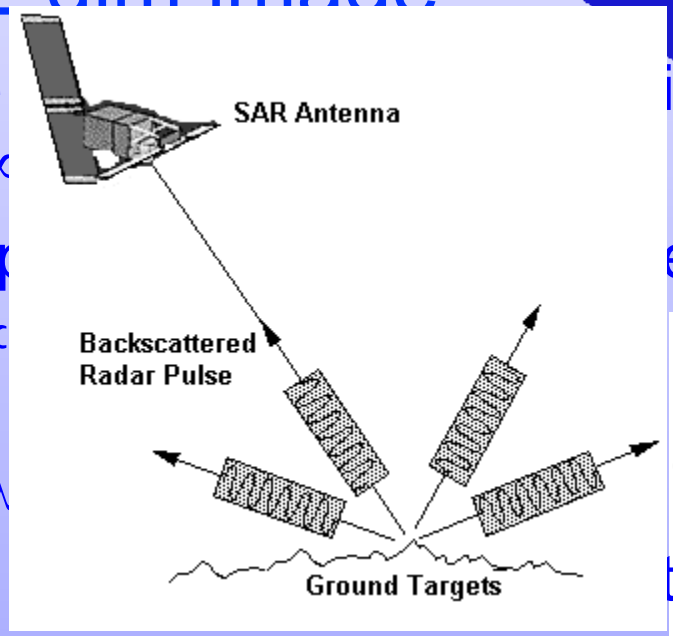


2-dim image

ission and echo

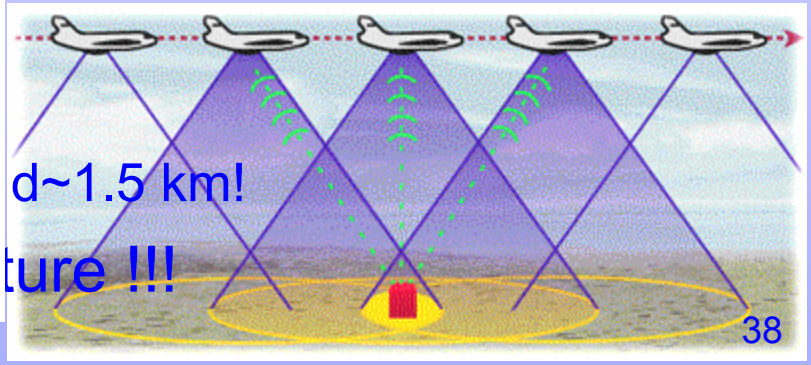
esolution ∝ beam



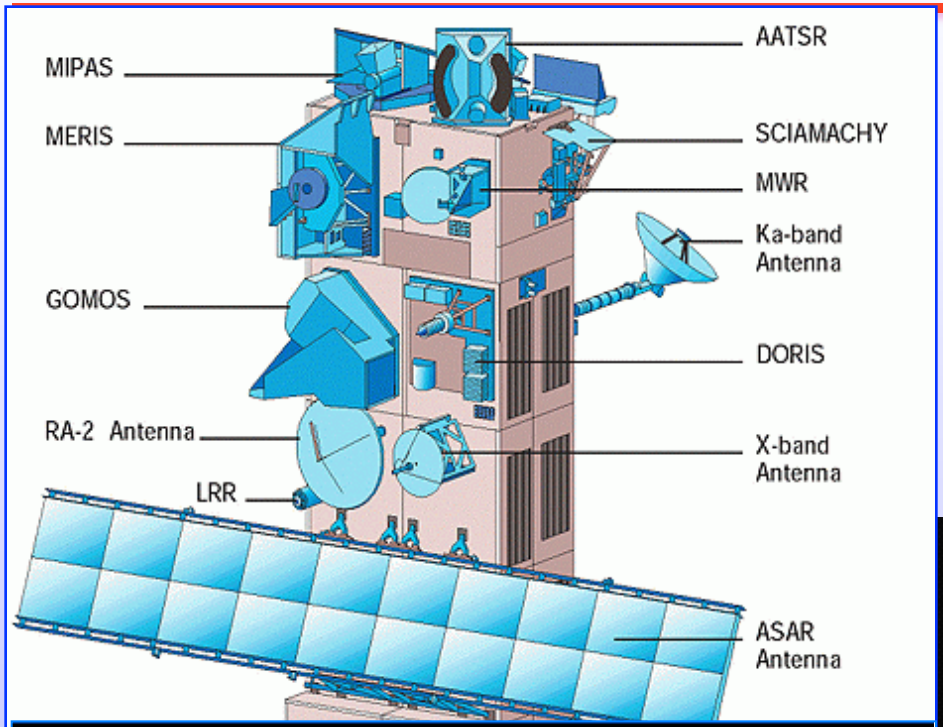


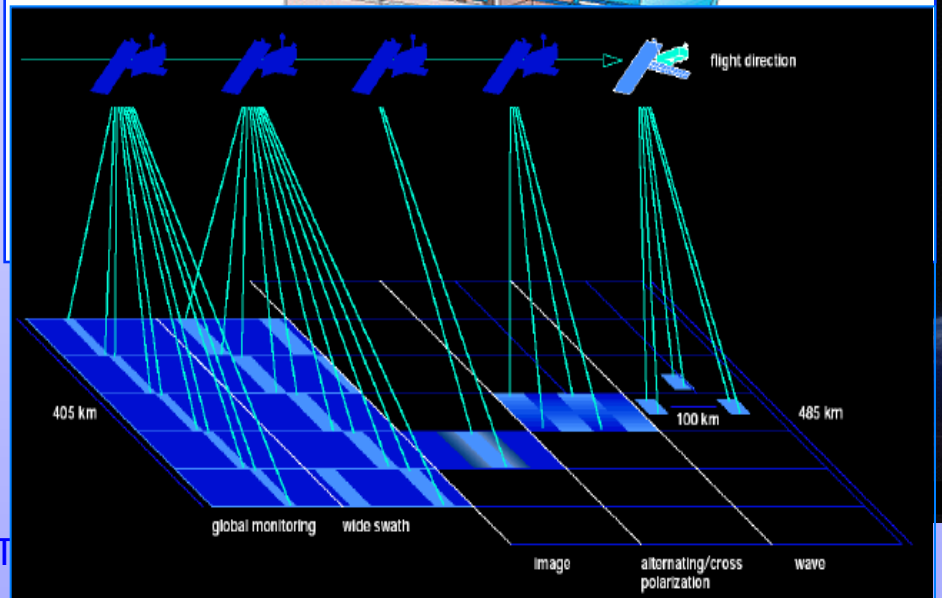
d~1.5 km!

ture !!!



Strumenti di Envisat

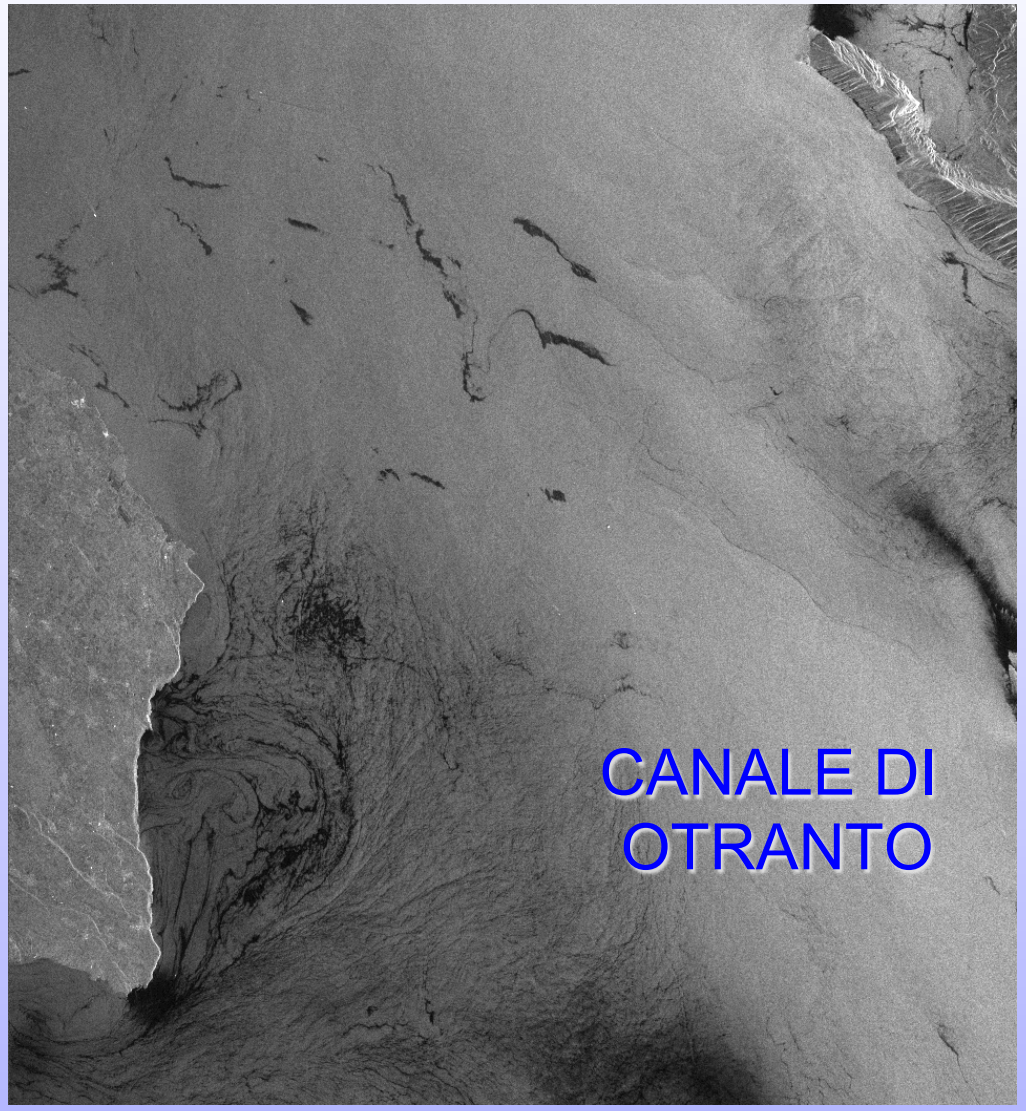




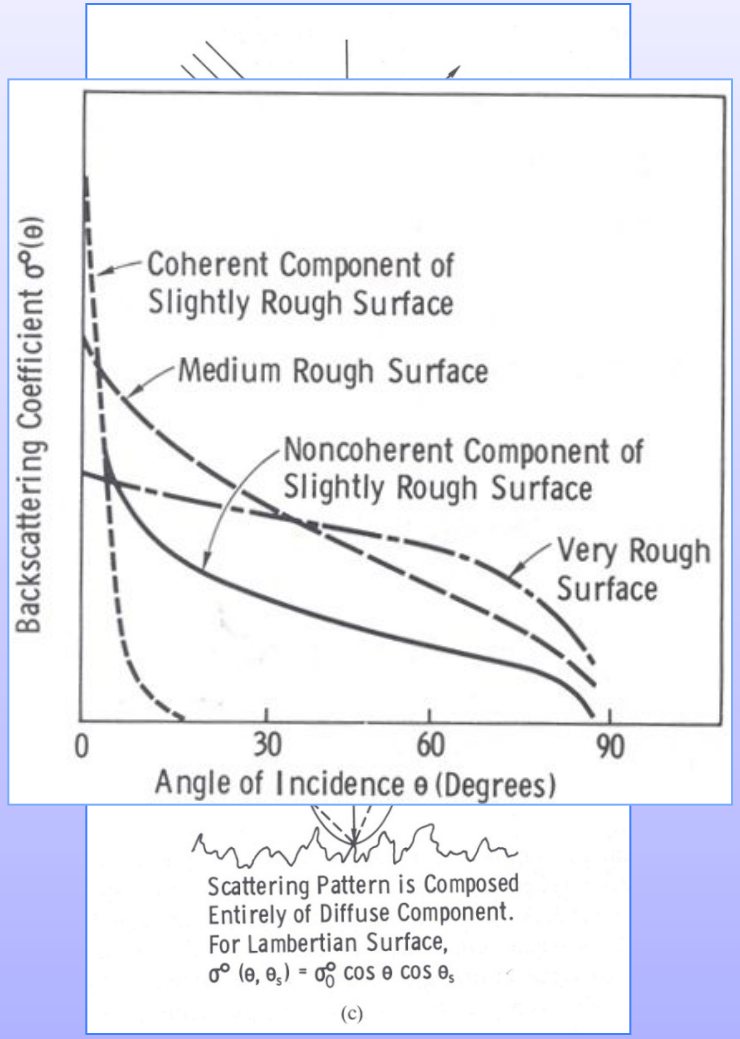
ASAR: Advanced Synthetic Aperture Radar

Immagini radar ad alta risoluzione dell'ambiente terrestre in qualsiasi condizione ambientale e di illuminazione

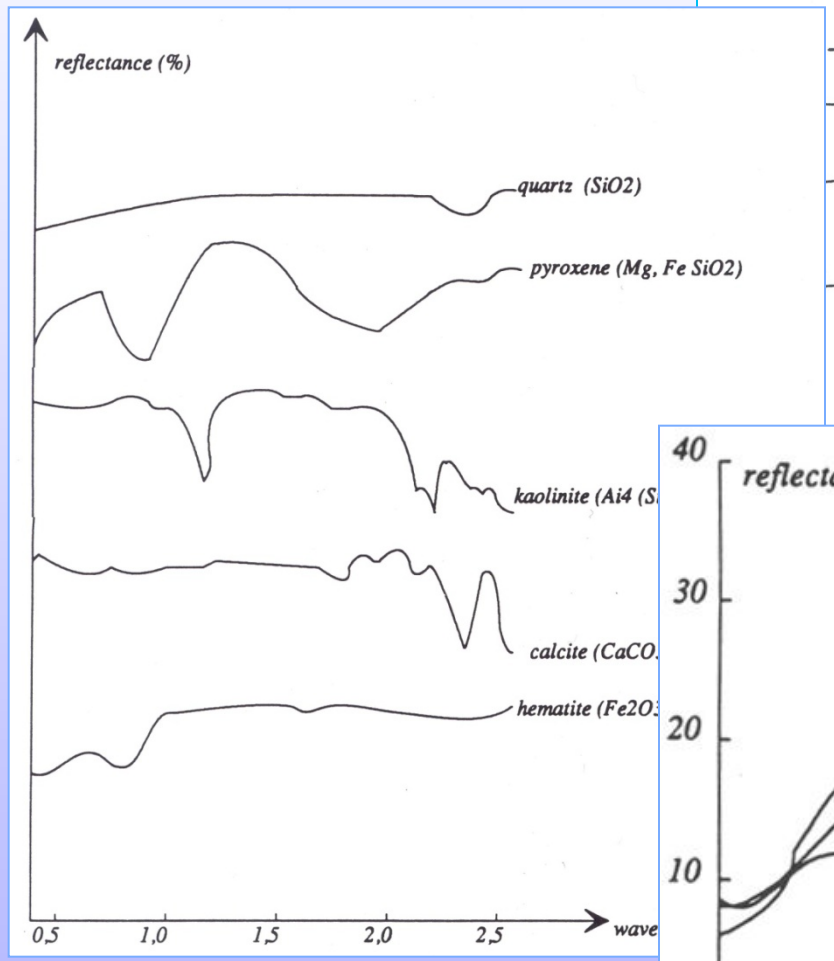
Imaging Radar: light reflectance, back-scattering

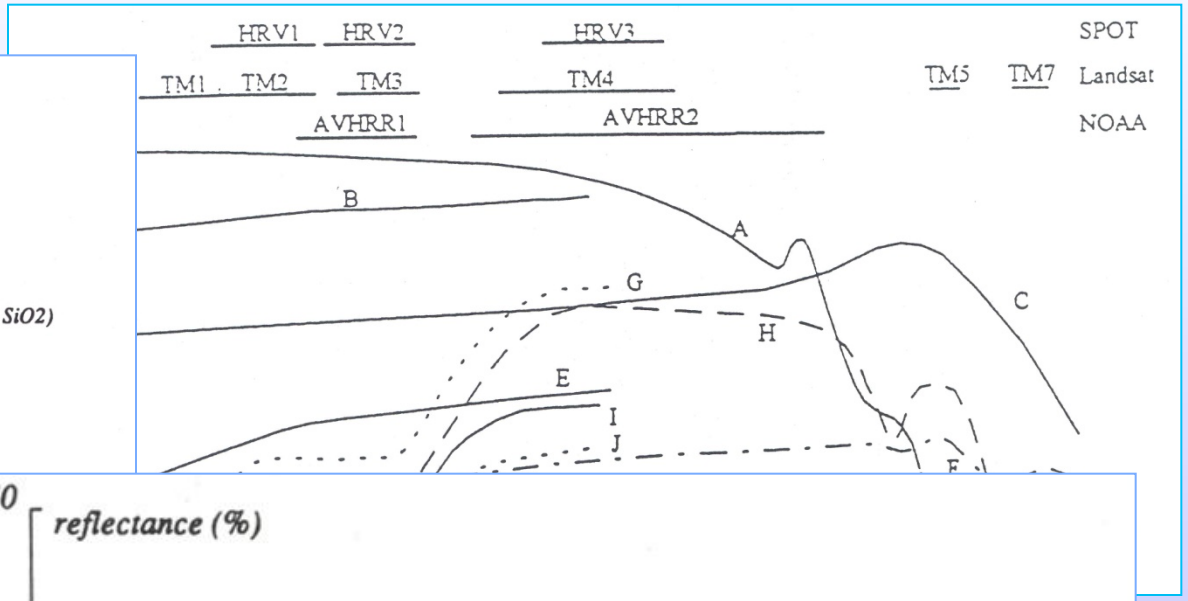


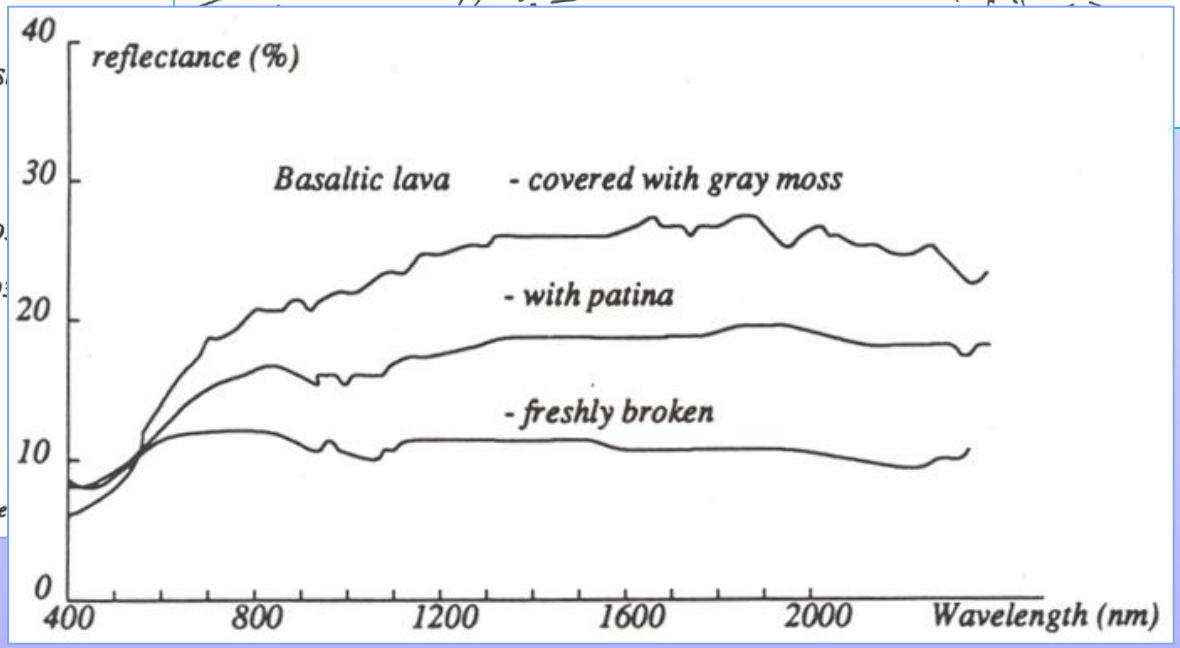
Surface rugosity is the second primary driver in radar signature



Geologia: struttura del suolo



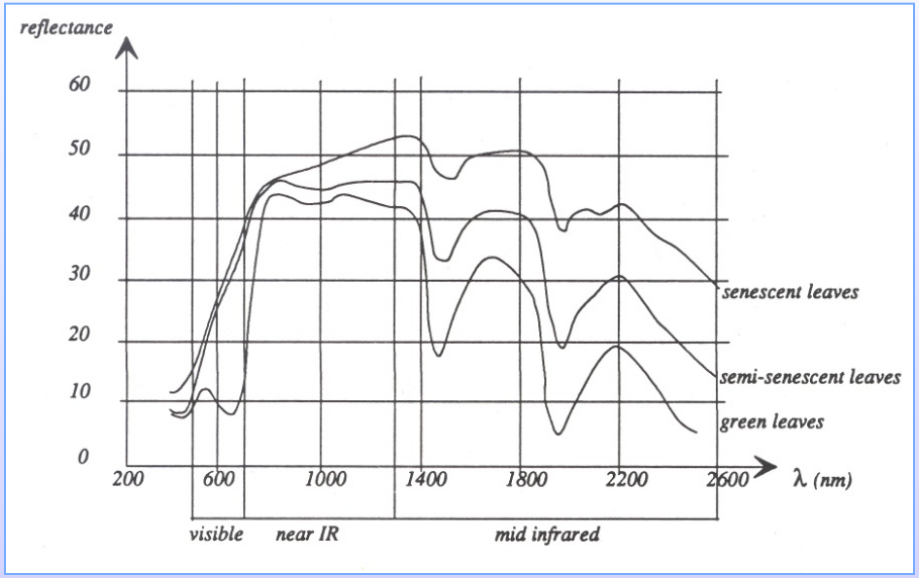


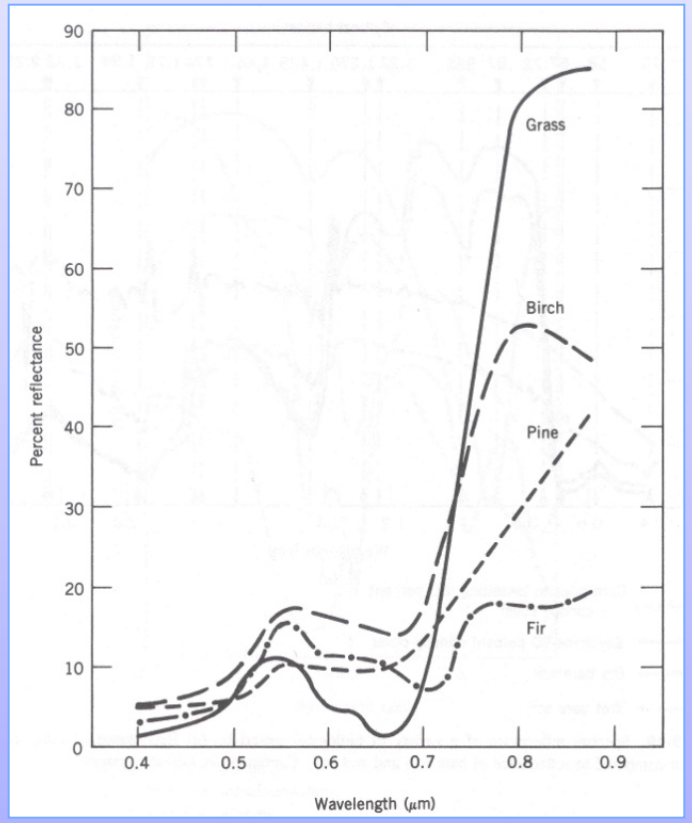


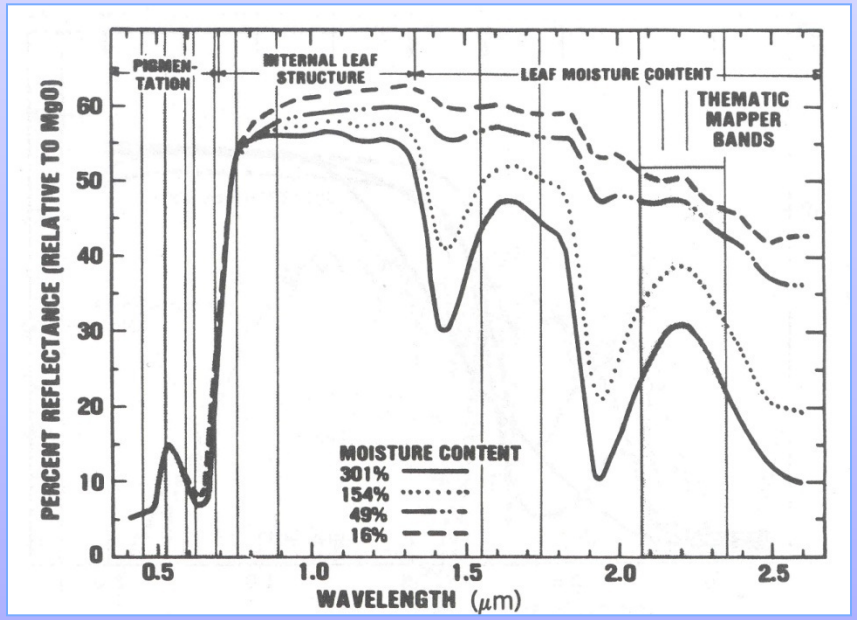
Biologia: vegetazione

Vegetation spectral signatures vary with

- leaf state
- canopy species
- leaf moisture content
- phenological stage



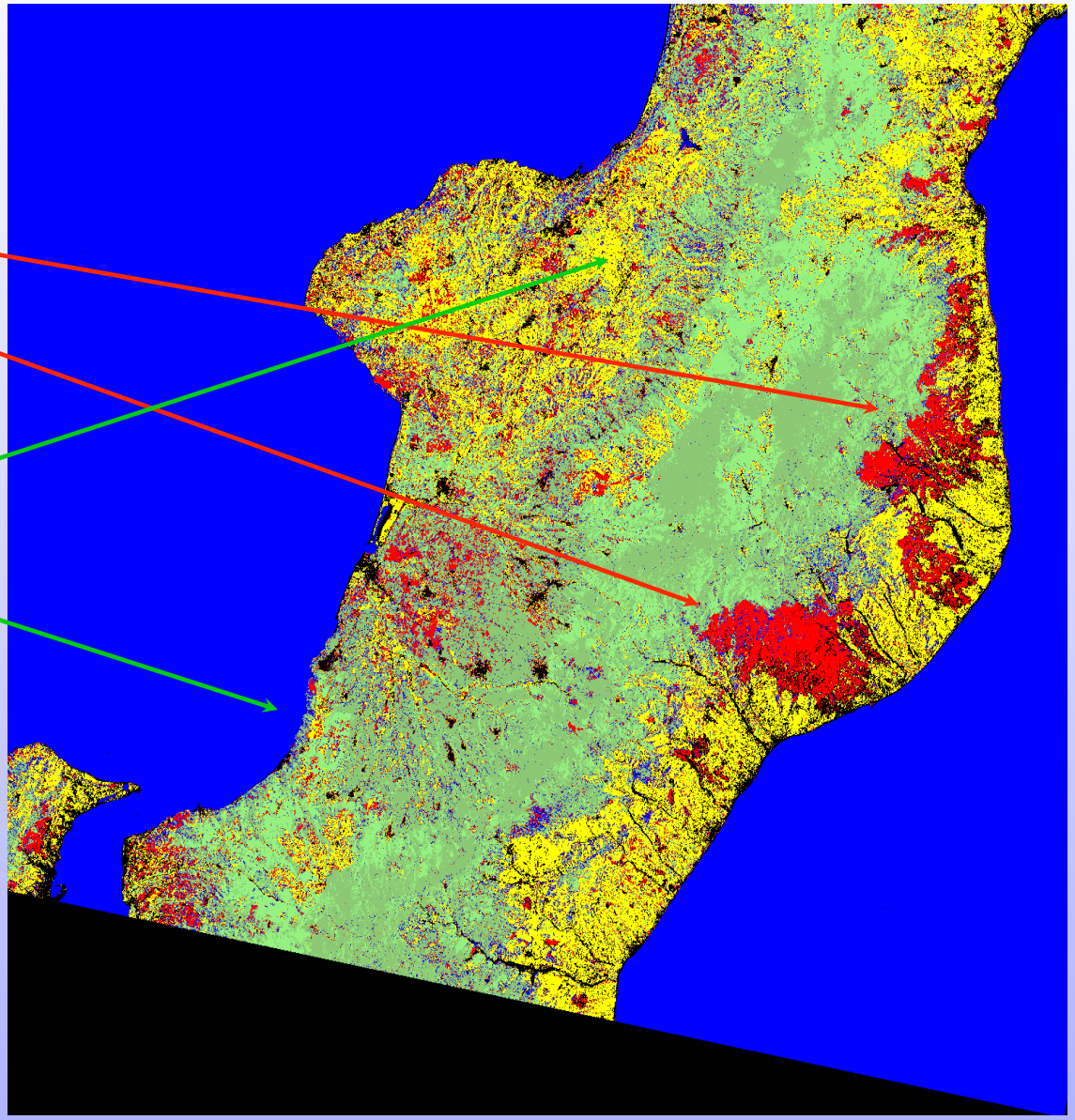




Ambiente: Controllo Incendi

incendi

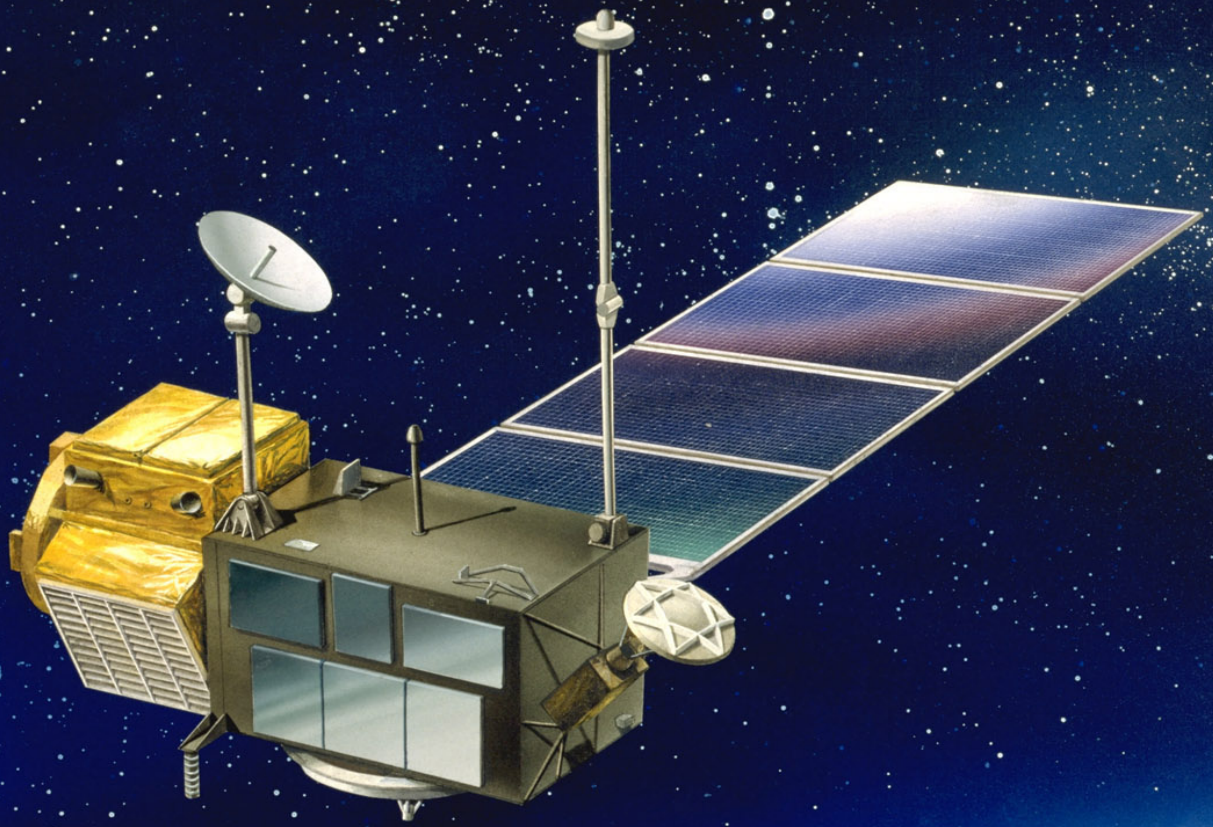
zone calde



Osservazioni Della Terra

Trieste, 3 ottobre 2012

TOPEX-POSEIDON: Studio degli Oceani



cnes
CENTRE NATIONAL D'ETUDES SPATIALES

DORIS

The DORIS system uses a ground network of 50 orbitography beacons around the globe, which send signals at two frequencies to a receiver on the satellite. The relative motion of the satellite generates a shift in the signal's frequency (called the Doppler shift) that is measured to derive the satellite's velocity. These data are then assimilated in orbit determination models to keep permanent track of the satellite's precise position (to within three centimetres) on its orbit. (Instrument supplied by CNES)

LRA

The Laser Retroreflector Array (LRA) provides a target for laser tracking measurements from the ground. By analysing the round-trip time of the laser beam, we can locate where the satellite is on its orbit. (Instrument supplied by NASA).

POSEIDON-1 altimeter on TOPEX/POSEIDON, it is a compact, low-power, low-mass

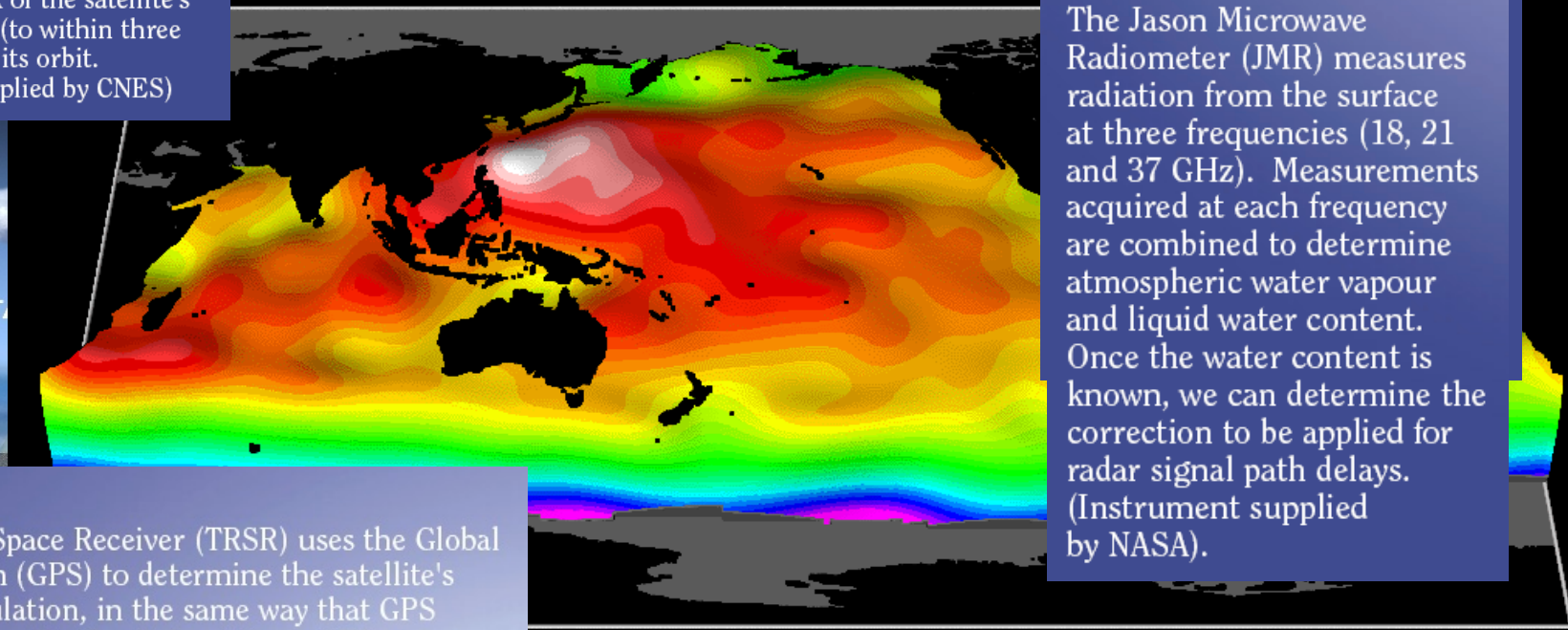
JMR

The Jason Microwave Radiometer (JMR) measures radiation from the surface at three frequencies (18, 21 and 37 GHz). Measurements acquired at each frequency are combined to determine atmospheric water vapour and liquid water content. Once the water content is known, we can determine the correction to be applied for radar signal path delays. (Instrument supplied by NASA).

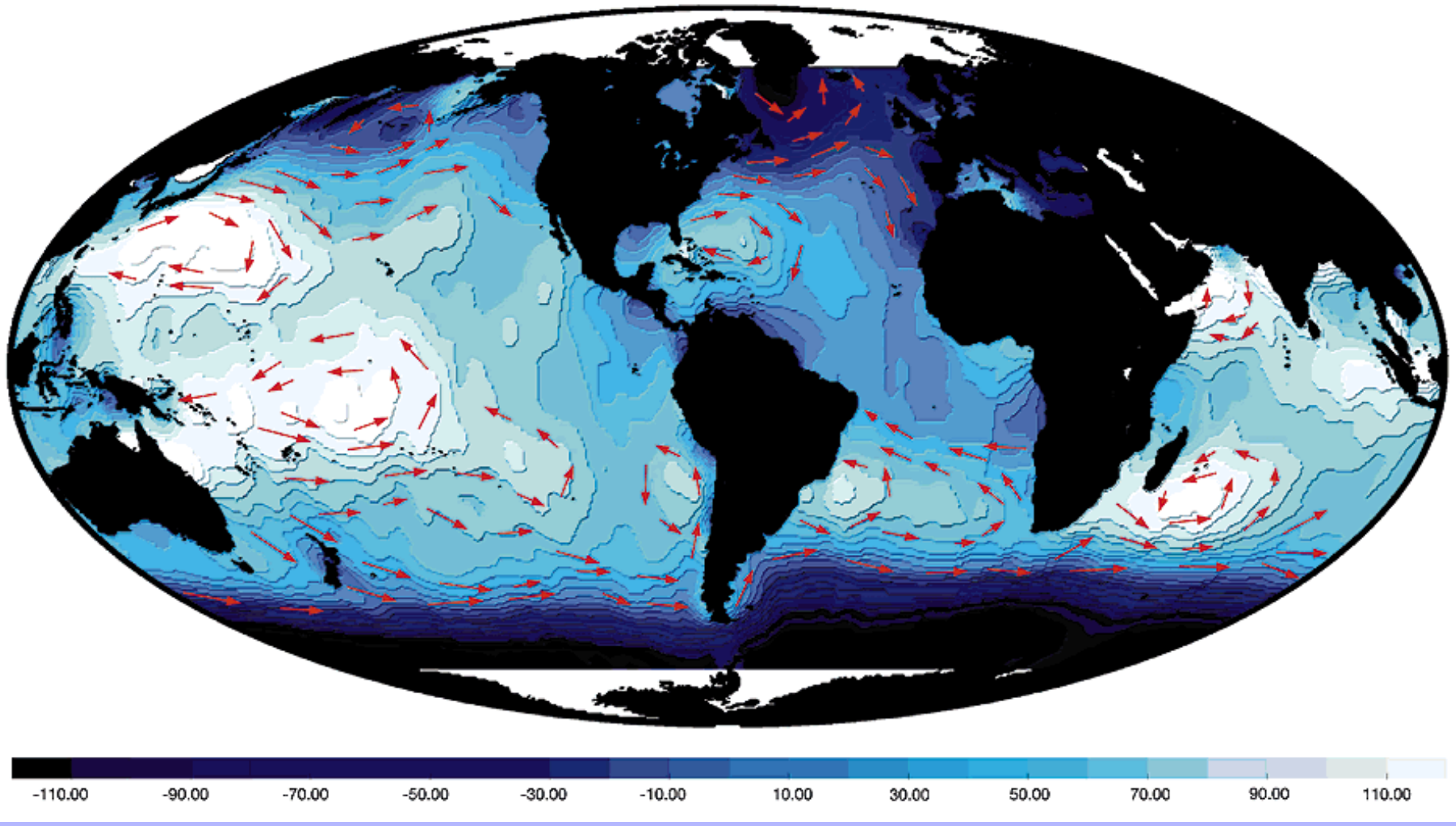
LASER ST

TRSR

The Turbo Rogue Space Receiver (TRSR) uses the Global Positioning System (GPS) to determine the satellite's position by triangulation, in the same way that GPS fixes are obtained on Earth. At least three GPS satellites determine the mobile's exact position at a given instant. Positional data are then integrated into an orbit determination model to track the satellite's trajectory continuously.



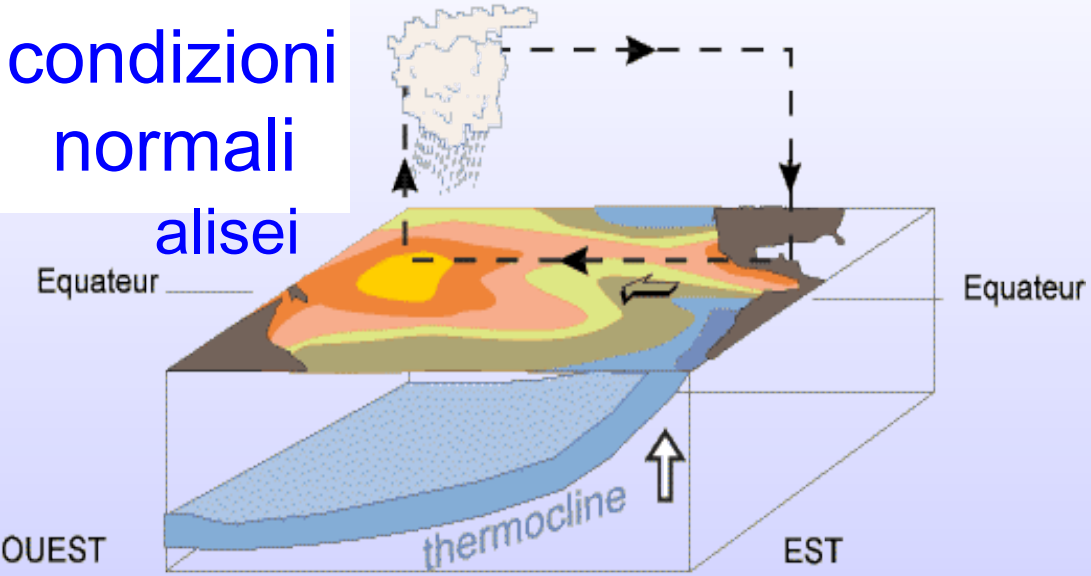
Dinamica degli Oceani

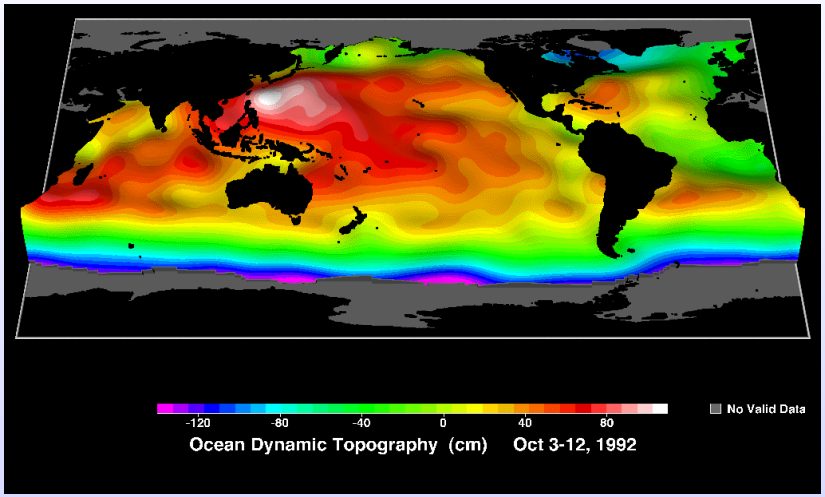


El Niño / La Niña

condizioni normali

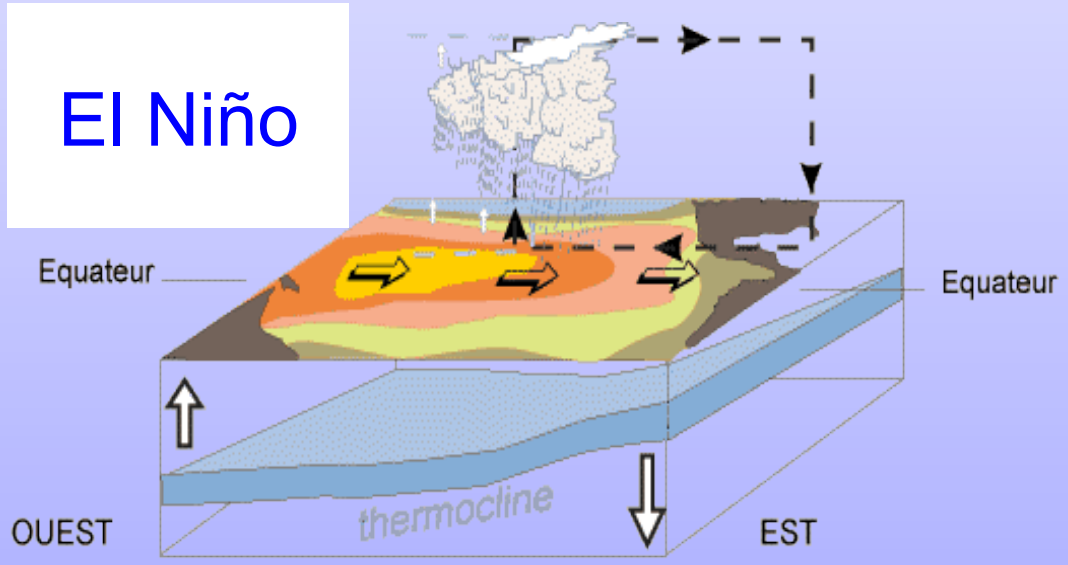
alisei



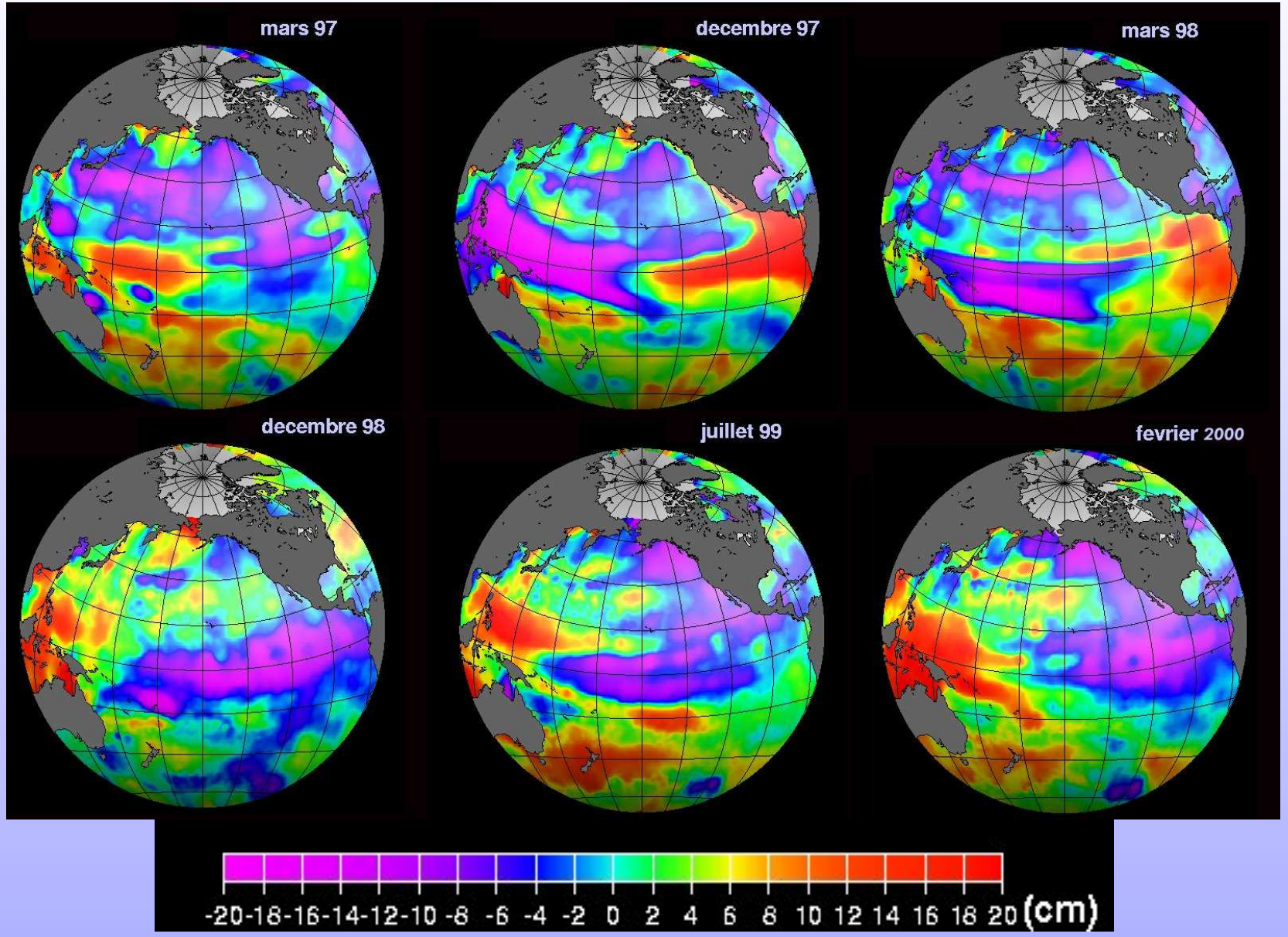


Fine primavera/inizio estate: monsoni

El Niño

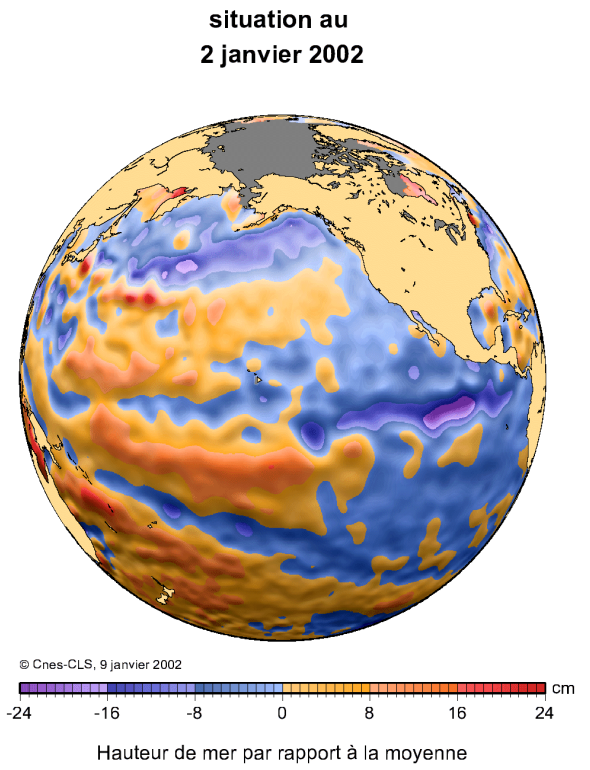


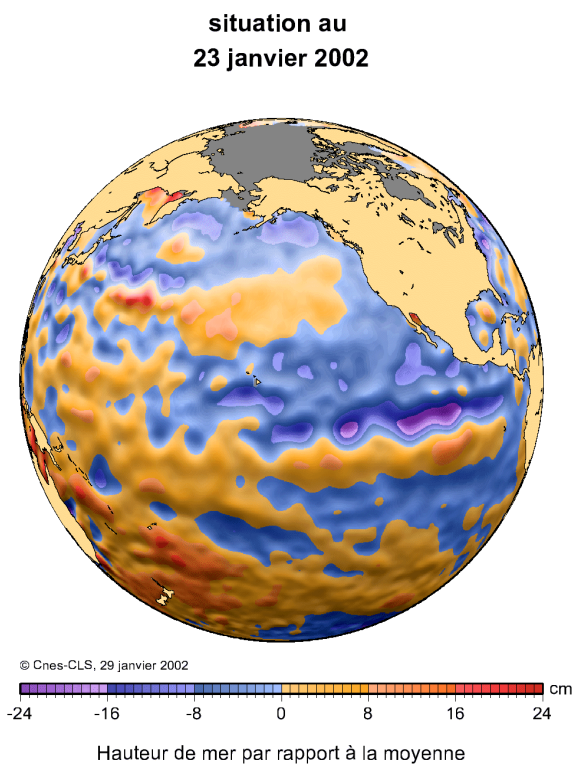
El Niño / La Niña



“Futuro ...”

Esempio del 2002





Fisica della Terra

ENVISAT

Scienza: Biologia

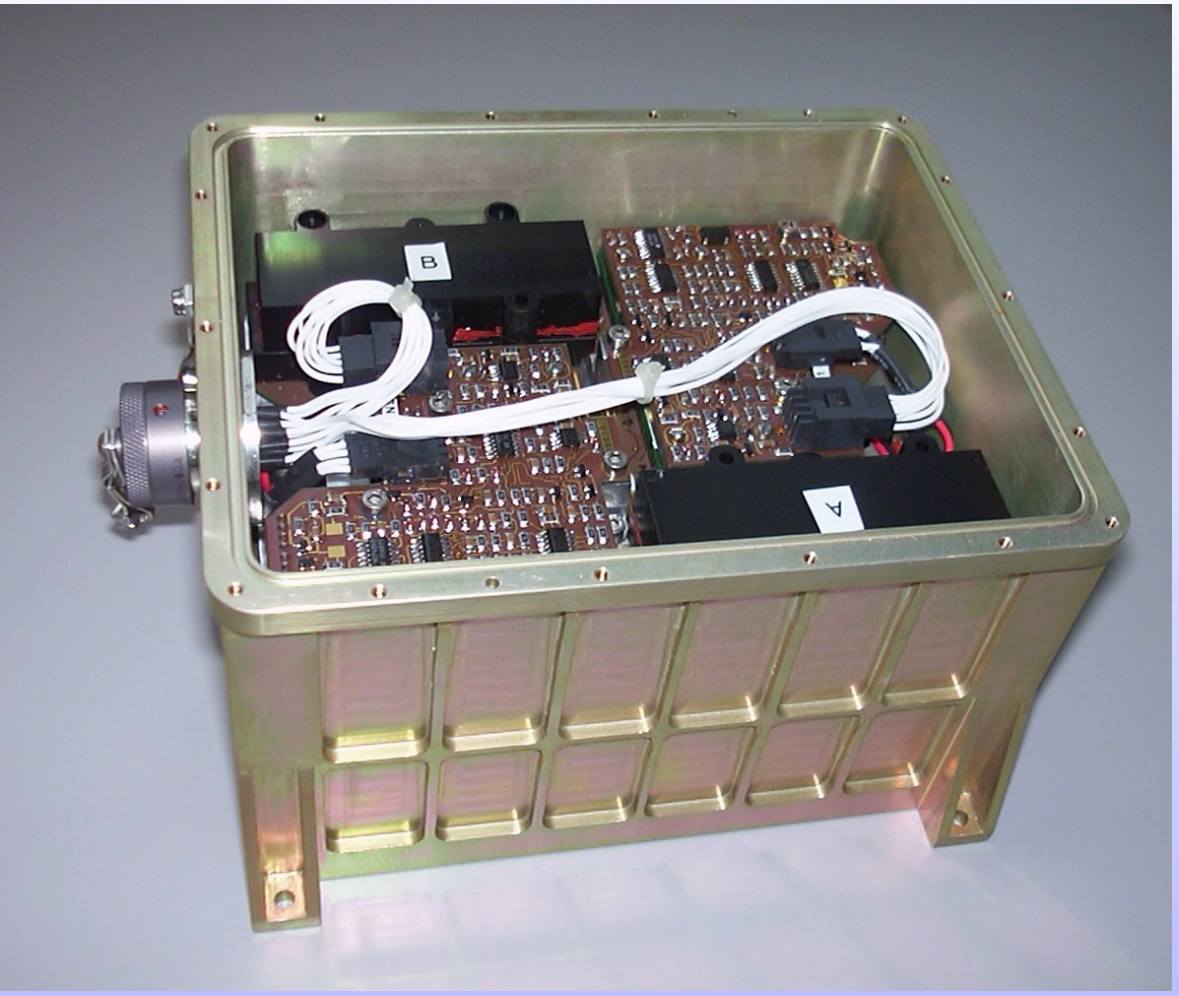
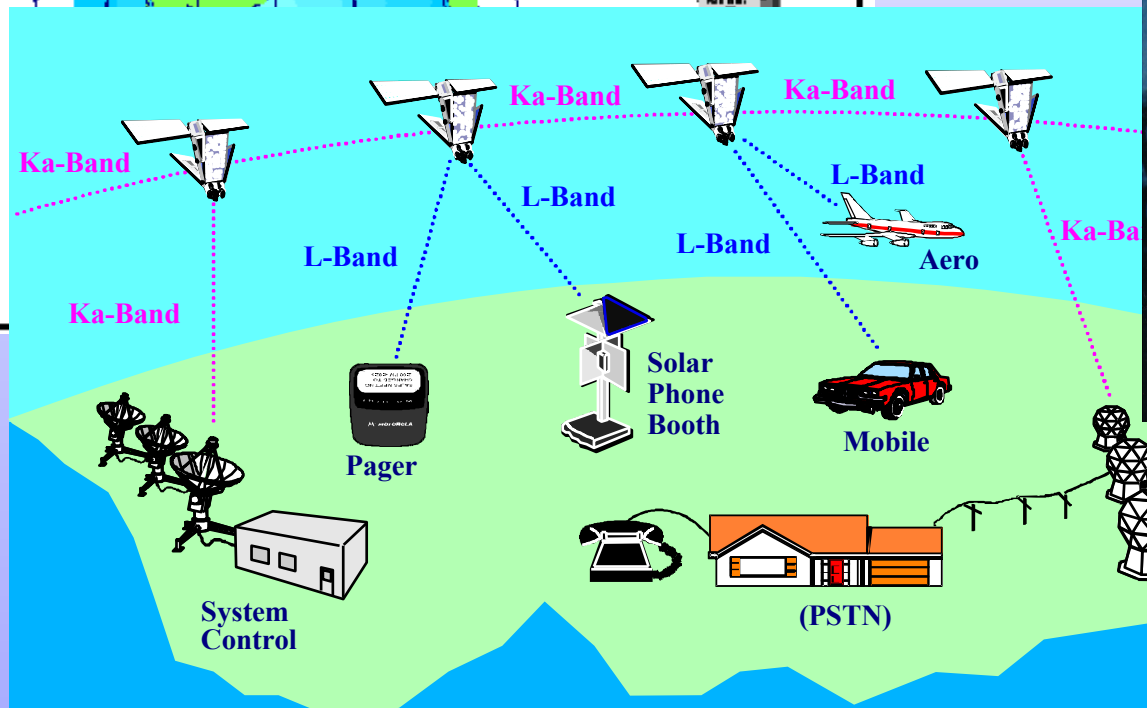


PHOTO II:

misure dedicate per la BIOLOGIA

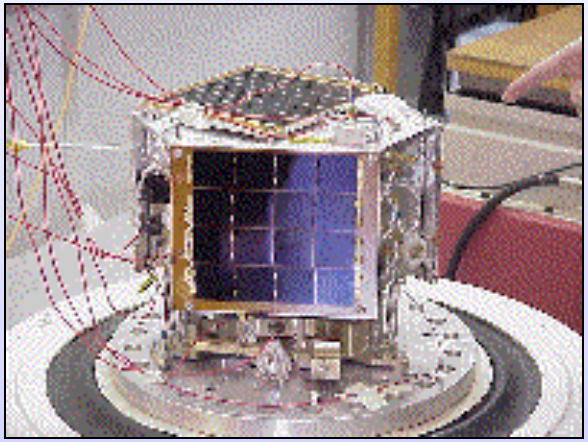
Programmi Commerciali: IRIDIUM



Programmi Educativi

Easy Space

SSTL



CUBESAT

ATMOCUBE/CUBESAT

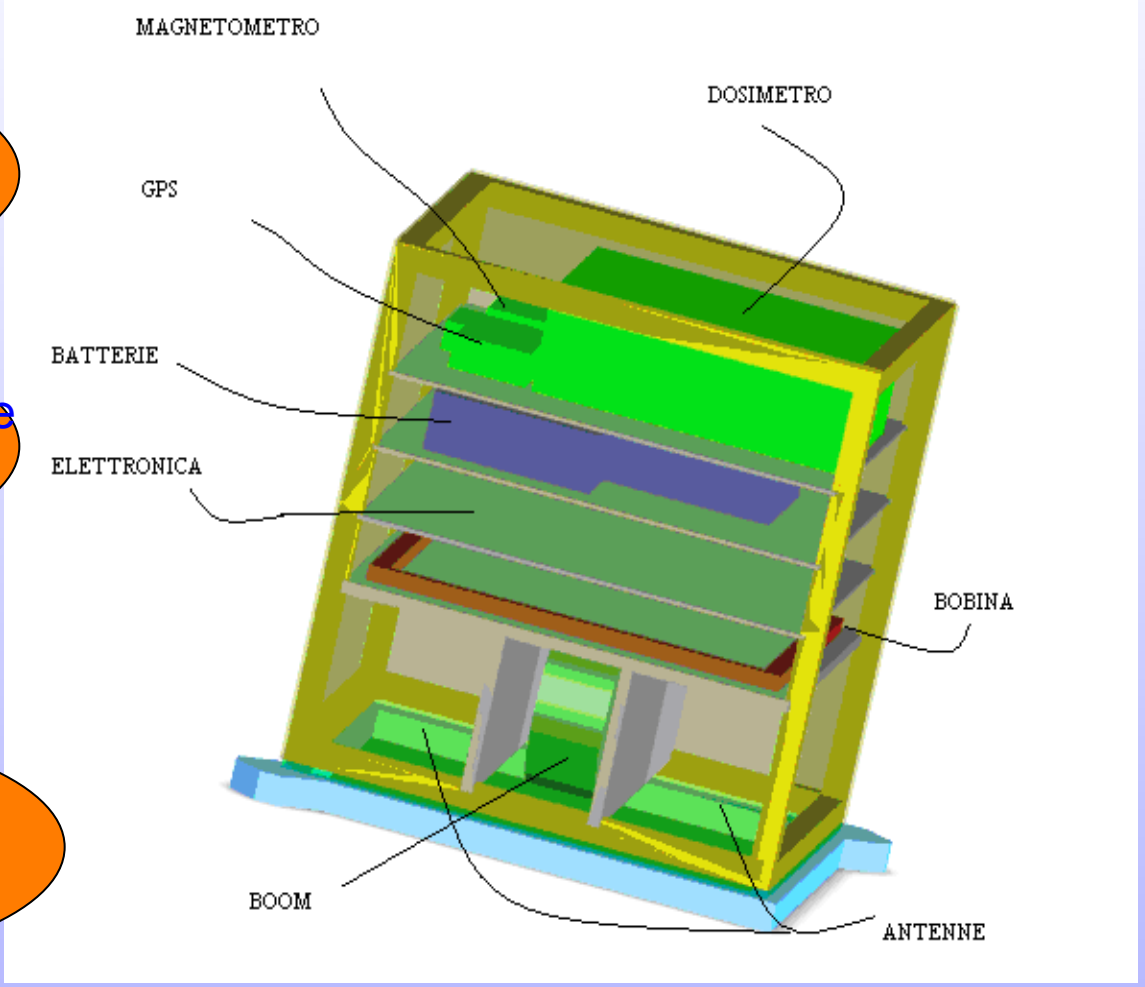
GOAL: Costruire una MAPPA precisa di

Campo Magnetico Terrestre

Flusso di Radiazione che incide su AtmoCube

e ...

COINVOLGERE STUDENTI !



Processo di Analisi

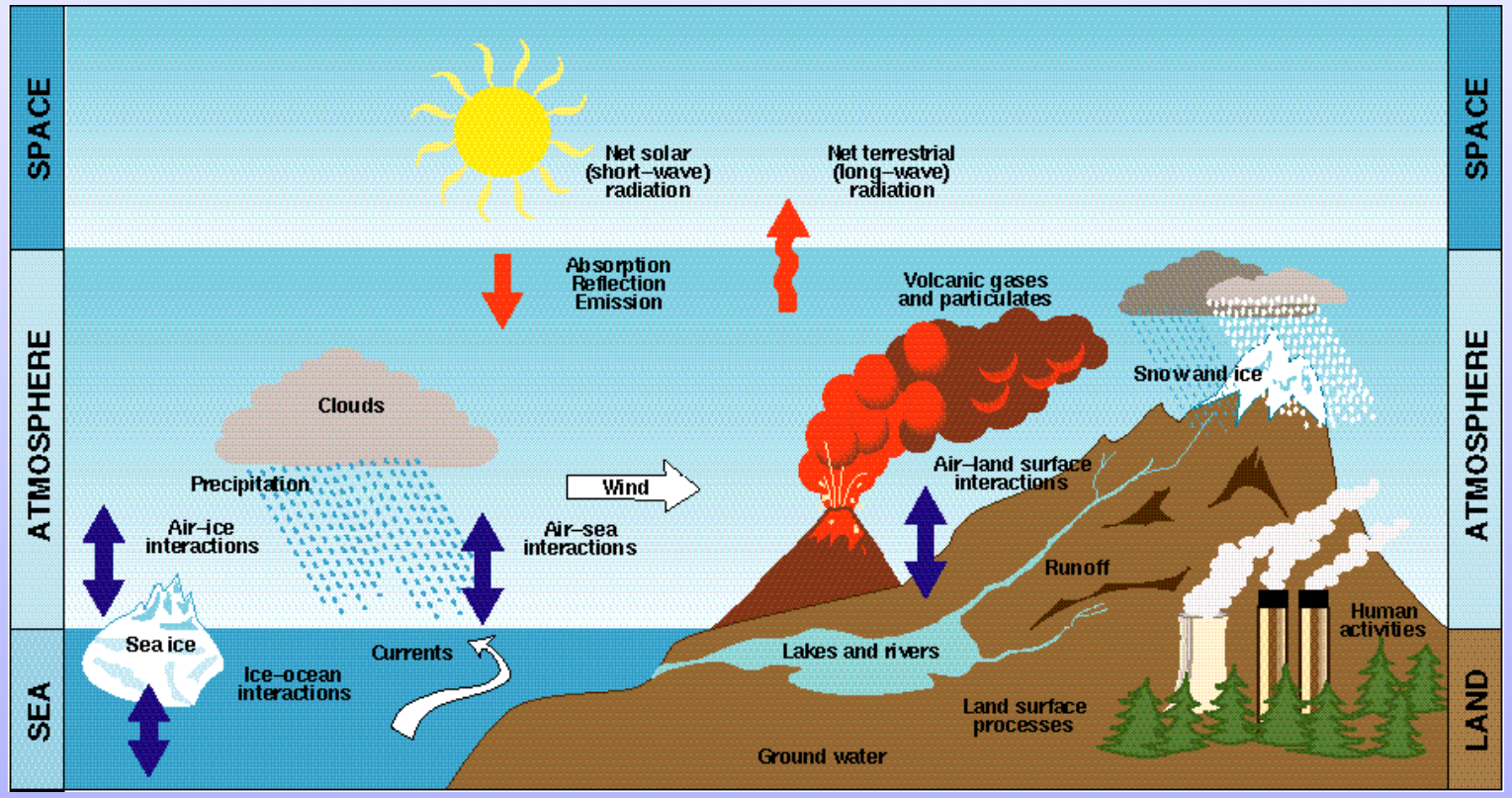
- Misura scientifica: Studio dell'Atmosfera Terrestre "SPACE-WEATHER"
  - Misura del Flusso di Radiazione sul satellite
  - Misura del Campo Magnetico in cui è immerso il satellite

- Problematiche:
  - Costi limitati: sistema molto semplice, molto piccolo e molto leggero
    - Cubo di lato 10 cm
    - Peso 1 kg
    - Potenza 2÷3 W
    - Evitare parti mobili se possibile
    - Utilizzo lanciatore (missile) disponibile: orbita non ottimizzata
  - Strumentazione non dedicata: commerciale
    - Accuratezza della misura limitata
    - Quantità di dati trasferibili limitata (banda radio-amatori)
  - Evitare interferenze con le misure (campo magnetico):
    - Uso limitato di sistemi elettromagnetici (bobine)
    - Separazione della strumentazione scientifica dall'elettronica: modulazione del satellite
  - Controllo dell'assetto del satellite
    - Gravity Gradient Boom + accessori

SPACE WEATHER 1/3

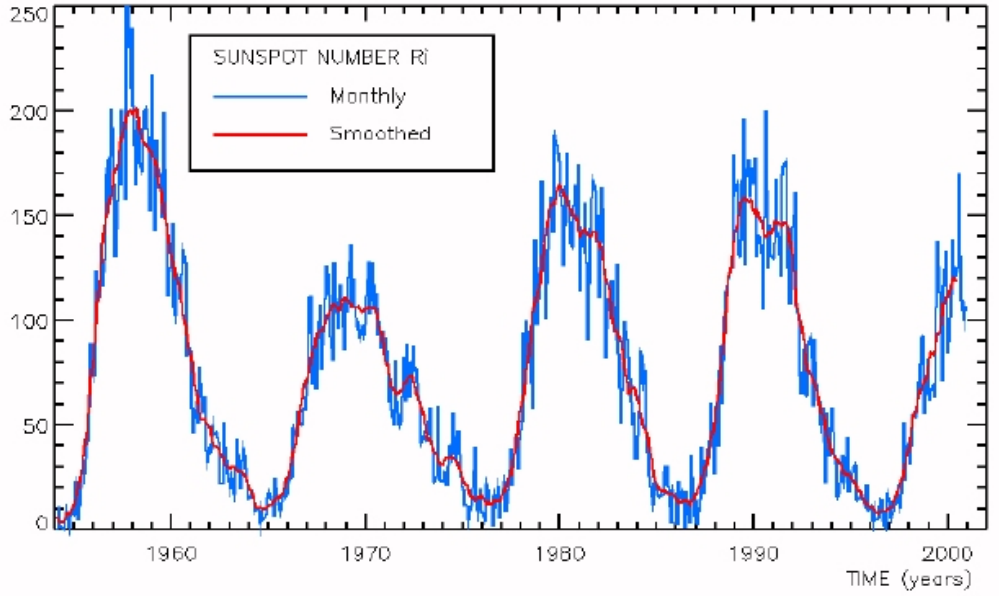
"Space Weather: condizioni sul Sole e sul vento solare, sulla magnetosfera, ionosfera, termosfera, che possono influenzare le prestazioni e l'affidabilità dei sistemi tecnologici nello spazio e a terra e possono mettere in pericolo la vita e la salute umana."

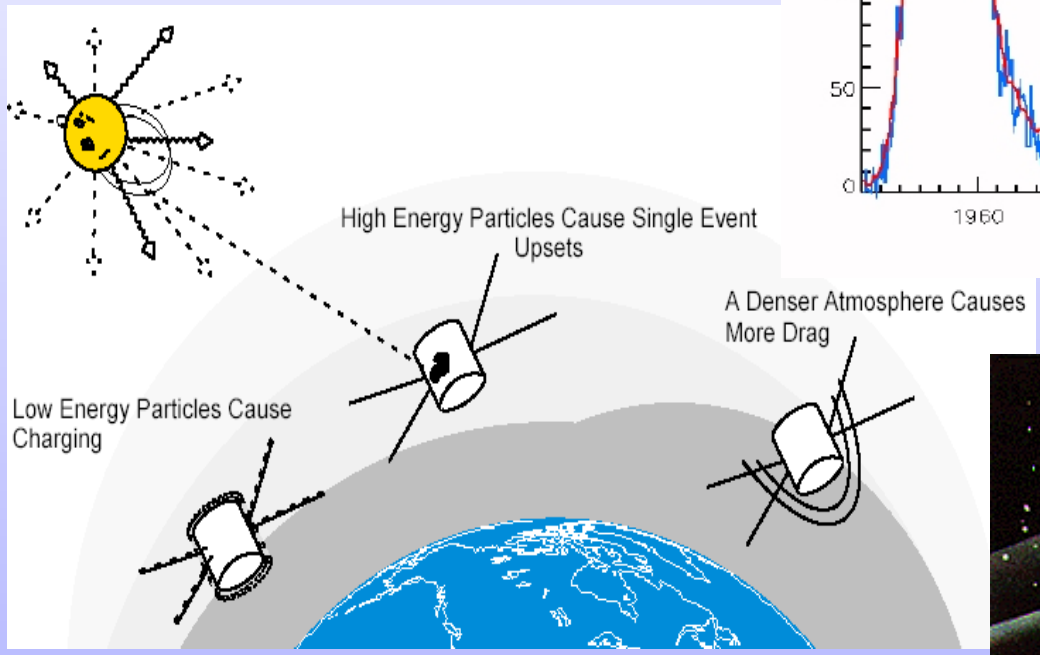
ESA website: www.esa.int

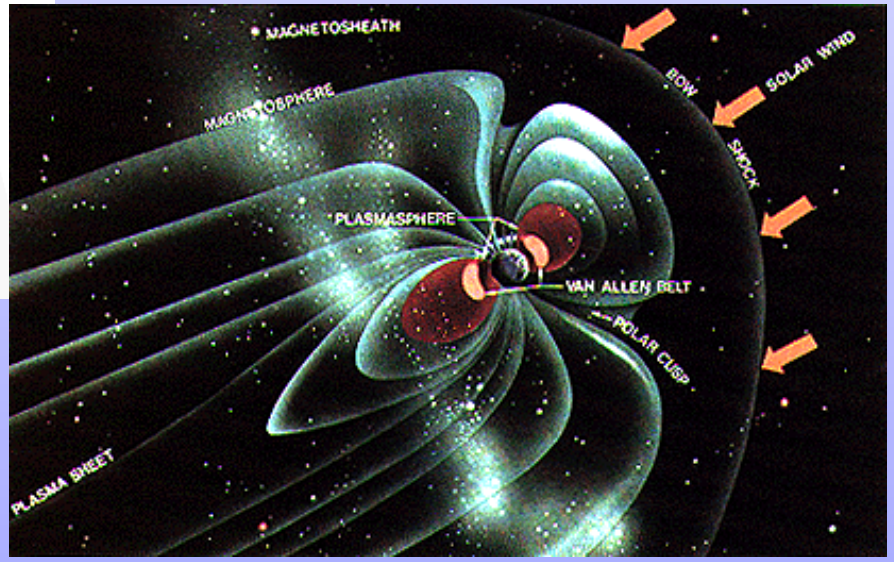


SPACE WEATHER 2/3

Sole: nel visibile
COSTANTE MA ….





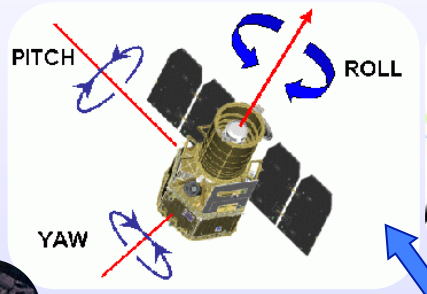


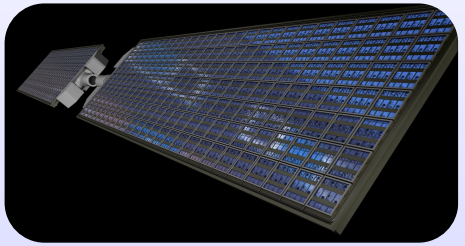
Trieste, 3 ottobre 2012

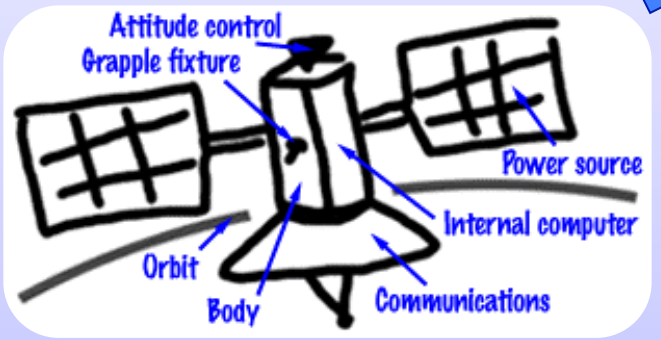
SPACE WEATHER 3/3

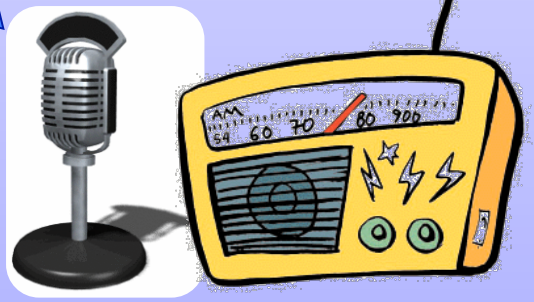
- effetti su S/C & aerei (total dose, lattice displacement, single events upsets (SEU), sensor bkg, spacecraft charging, drag)
- reti distribuzione energia (guasti su linee di alimentazione, effetti di corrosione nelle condutture -Quebec marzo 1989)
- sistemi comunicazione (cambiamenti struttura della ionosfera: aumento assorbimento, riflessioni inattese, interferenza radio, interruzioni comunicazioni)
- rischi per la salute umana (astronauti e equipaggi aerei soggetti a dosi elevate di radiazione)
- cambiamenti climatici (emissioni solari UV modificano strato ozono ed influenzano circolazione dell'aria su grande scala, raffiche vento solare modificano proprietà elettriche parte superiore dell'atmosfera e influenzano gli strati bassi dell'atmosfera, nel minimo solare vento solare -più debole- permette agli GCR di penetrare più facilmente nell'atmosfera terrestre promuovendo formazione nubi di bassa quota)

I Sistemi di un Satellite 1/2

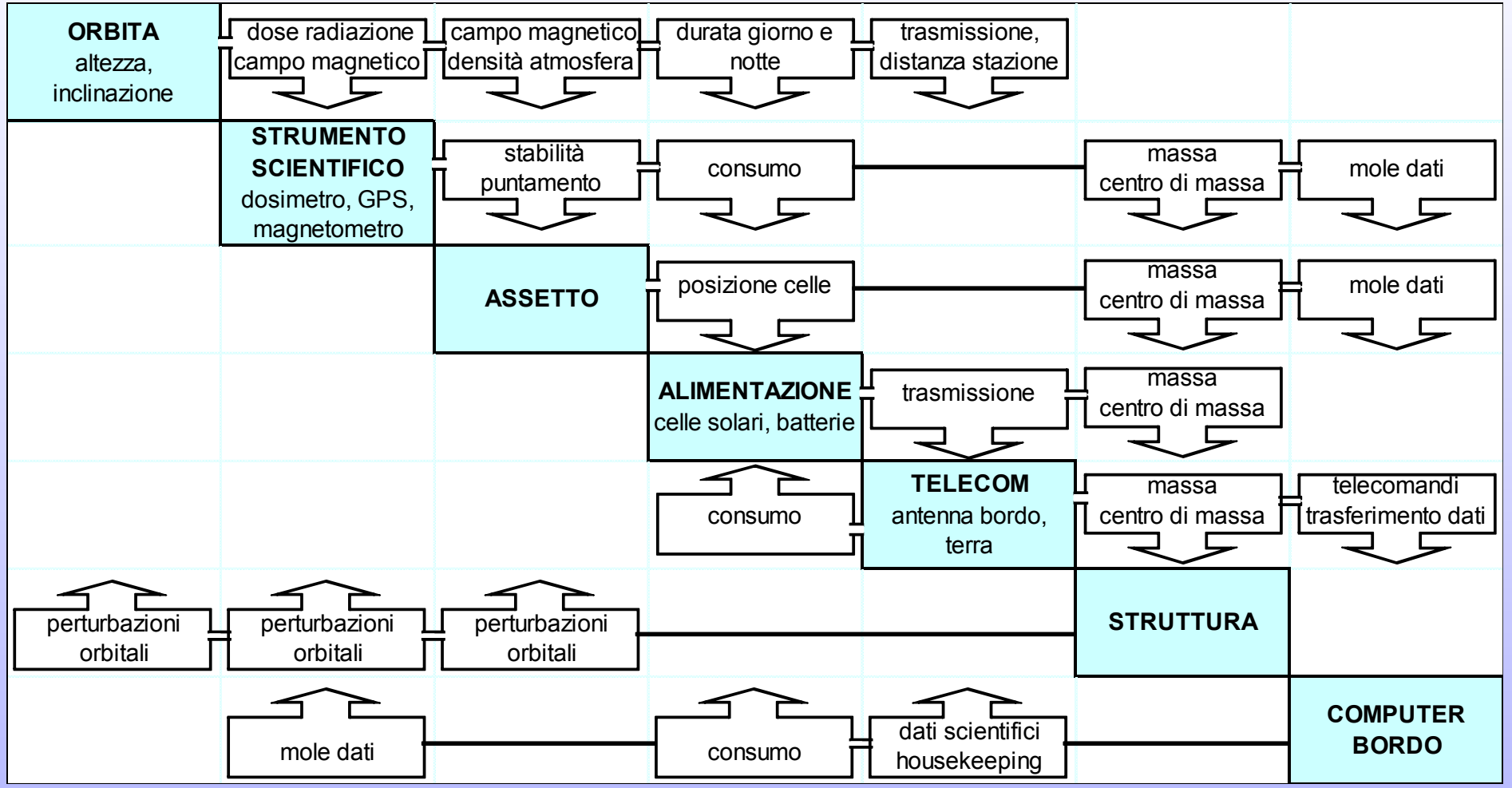








I Sistemi di un Satellite 2/2



Ruolo della Fisica Spaziale

Studia le relazioni fra la Terra e l'umanità considerando anche la Terra come un sistema di cui vanno analizzati i cambiamenti globali.

Studia la Terra come un pianeta anche per mezzo dello studio degli altri pianeti e con le tecniche della planetologia comparativa.

Studia il Sole, non solo come unica fonte di tutta la nostra energia, ma anche come una stella utilizzando l'astrofisica stellare osservativa e teorica per caratterizzare la nascita, l'evoluzione e la fine delle stelle e dei sistemi stellari.

Studia il posto dell'uomo nel Cosmo attraverso la comprensione della vastità dello spazio e del tempo ed attraverso lo studio dei problemi fondamentali sull'origine, l'evoluzione ed il destino dell'Universo.

Studia l'origine ed il valore della vita attraverso l'analisi delle molecole organiche di natura extraterrestre, incluse le molecole del mezzo interstellare, l'analisi chimico-fisica delle atmosfere di mondi come Giove e Titano, o di pianeti come Marte che una volta possono essersi trovati in condizioni adatte allo sviluppo d'organismi viventi simili a quelli terrestri, la ricerca di pianeti esterni al sistema solare, la ricerca di vita extraterrestre.

Studia le leggi che governano le proprietà dei materiali, d'aggregati e di macchine quando sono sottoposti alle condizioni estreme di gravità, temperatura, vuoto, flussi di particelle cariche che si trovano nello spazio.

Conclusioni

- TECNOLOGIA
  - proprietà dei materiali
  - comunicazioni
- RISULTATI SCIENTIFICI
  - Sole e di altre stelle (astrofisica & astronomia)
  - Universo (cosmologia)
  - Pianeta Terra (planetologia)
  - Origine della vita, dell'atmosfera, dell'ambiente…
- CONNESSIONE CON ALTRI CAMPI
  - biologia, chimica, ingegneria …